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Terminology Service Development at the Mayo Clinic

Harold Solbrig
Technical Specialist
Medical Informatics Research
Mayo Clinic
Rochester, MN 55901

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Outline

- **Background** – why terminology services?
- **Where we've been** – the evolution of terminology services at the Mayo Clinic
- **Where we are now** – current tools and approaches to terminology services
- **Where we are going** – technologies, distribution, future applications

Background

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Terminology

The lexicon of a special subject language reflects the organisational characteristics of the discipline by tending to provide as many lexical units as there are concepts…

Juan C. Sager, *A Practical Course in Terminology Processing.* John Benjamins, 1990

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Terminology

The items which are characterised by special reference within a discipline are the 'terms' of the discipline, and collectively they form its 'terminology'; those which function in general reference over a variety of sublanguages are simply called 'words', and their totality the 'vocabulary'.

Juan C. Sager. *A Practical Course in Terminology Processing*

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Evolutionary Steps of a Terminology

1) **Everyday words (vocabulary)** - the differentiating knowledge of the trade or profession is in the formative stage.

2) **Overloaded words and/or acronyms** - As the knowledge increases, it becomes cumbersome to continue to use full phrases to express concepts. Common phrases are shortened: "*kernel, heap, garbage collection, SCRAM, LASER, ...*"

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Evolutionary Steps of a Terminology

3) **Formalized nomenclature** - as the need for precision and detail increases, the management of haphazard wording becomes prohibited. When practical, formalized naming rules are established. *Linnaeus system, chemical names, SNOMED, etc.*

4) **Coding and classification schemes** - as specialties and different views emerge, the need to classify, categorize and cross-reference becomes important. *ICD, etc.*

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Evolutionary Steps of a Terminology

5) **Thesauri** - Boundaries between specialties change and cross references become necessary between terminologies of different specialties. *UMLS*

6) **Reference Terminologies** - Thesauri become unwieldy and too imprecise. A new, synthetic, atomic conceptual organization is formed as a reference point and focus. *SNOMED-CT, Read Codes III*

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Terminological Categories

"First Generation" terminological systems

- Typically targeted for paper based information systems (not "IT-enabled")
- Simple hierarchies and organization
- Expensive to maintain and reuse

Angelo Rossi Mori, et. al. *Standards to support development of terminological systems for healthcare telematics.*

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Terminological Categories

“Second Generation” systems

- Compositional systems, based on a *categorial structure* (semantic categories, semantic links [associations between categories])
- Dynamic organization, systematic description of a subject field
- Flexible and extensible
- Limited semantic based processing

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Terminological Categories

- **"Third Generation" systems**
  - Based on a formal model (a set of symbols and a set of formal rules)
  - Dynamic w/ multiple hierarchies
  - Content and updates are formally validated
  - Complete semantic based processing (behavior is independent of names)

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What is a terminology?

Key characteristics:

- Set of terms, definitions and relationships for a (relatively) non-ambiguous partitioning of the conceptual space of a specialized subject area or discipline.
- NOT necessarily related to computerized data processing (or even data processing, period)
- A formal shared context for communication among members of a specialty or trade.

What is a terminology?

- **Key characteristics**
  - Term ⟷ concept mapping
  - Additional entry phrases including
    - Lexical variants
    - Synonyms
    - Similar or related phrases
  - Intrinsic definitions, annotations, etc.
  - Extrinsic definitions in form of taxonomy / ontology / semantic net

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Terminology vs. Ontology

- The word “Ontology”, as it is used today refers to the DL-based organization of ‘concepts’
- Focus is on the formal organization
- Lexical/linguistic section is underspecified
  - Attributed definitions
  - Terms in multi-languages and contexts
- Behavioral characteristics are strictly DL – no rules on how to find a node given an input string...

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Uses of Terminology in Clinical Practice

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Terminology in Clinical Practice

Code Sets – Lists of codes used to fill out forms, data entry, etc.

- Drawn from small to medium size lists
- Typically local to institution
- May not cross databases or applications

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Code Sets in Forms

10. Complete the following information if the isolate is *vibrio cholerae 01 or 0139:*

Serotype (452) (check one)

_ Inaba (1)
_ Ogawa (2)
_ Hikojima (3)
_ Not Done (4)
_ Unk. (9)

Biotype (check one)

_ El Tor (1)
_ Classical (2)
_ Not Done (3)
_ Unk. (9)

Patient home state: _ _

4. Sex: (68)

_ M (1)
_ F (2)
_ Unk. (9)

The patient has been enrolled at:

1	NIH-sponsored
2	Other
3	None
9	Unknown

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Terminology in Clinical Practice

Classifications - Codes used to summarize information for the purpose of QA, reporting, reimbursement, etc.

- ICD-9-CM, CPT4, ...
- (Usually) Redundant information
- In use since (at least) the 16th century London Bills of Mortality

Terminology in Clinical Practice

Classifications

- **Shape and size of "buckets" depends on intended use**
  - "Killed by several Accidents"
  - "King's Evil"
  - "Frightened"
  - "Crushed by falling aircraft in terrorism [attack]"
  - "concussion with more than 24 hours loss of consciousness and return to pre-existing conscious level"

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Terminology in Clinical Practice

Indices – Codes used to summarize the content of medical records for the purpose of research and retrieval

- MESH, ICD-9-CM, HICDA, ...

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Terminology in Clinical Practice

Metadata – Codes that describe the format and content of databases, files, forms, etc.

- Enables sharing of information across institutions
- Enables sharing of information within institutions across time
- Only recently becoming formalized

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Terminology in Clinical Practice

- **Code Sets**
  - Often restrictive, incomplete
  - Lack of compositional structure
  - Not applicable in many settings (free text, quantitative data, etc.
- **Classifications**
  - Granularity depends on the context
  - Rarely matches the level of specificity needed to accurately record clinical information

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Terminology in Clinical Practice

- **Indices**
  - Classification after the fact
  - Can be labor intensive
  - Balance must be maintained between granularity and cost
  - Cannot anticipate unexpected requests
    - AIDS symptoms
    - Terrorism related events

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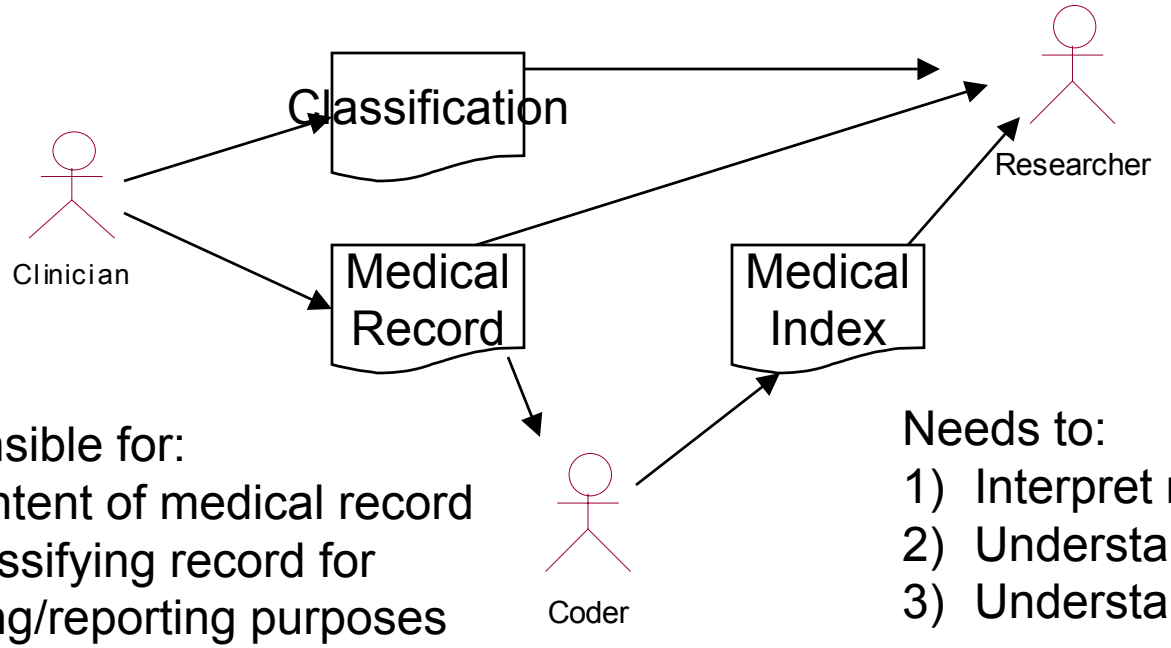
Terminology in Clinical Practice



Responsible for:
1) Content of medical record
2) Classifying record for billing/reporting purposes

Needs to:
1) Interpret record contents
2) Understand classification process
3) Understand indexing process

Responsible for:
1) Interpreting medical record
2) Classifying record for research purposes

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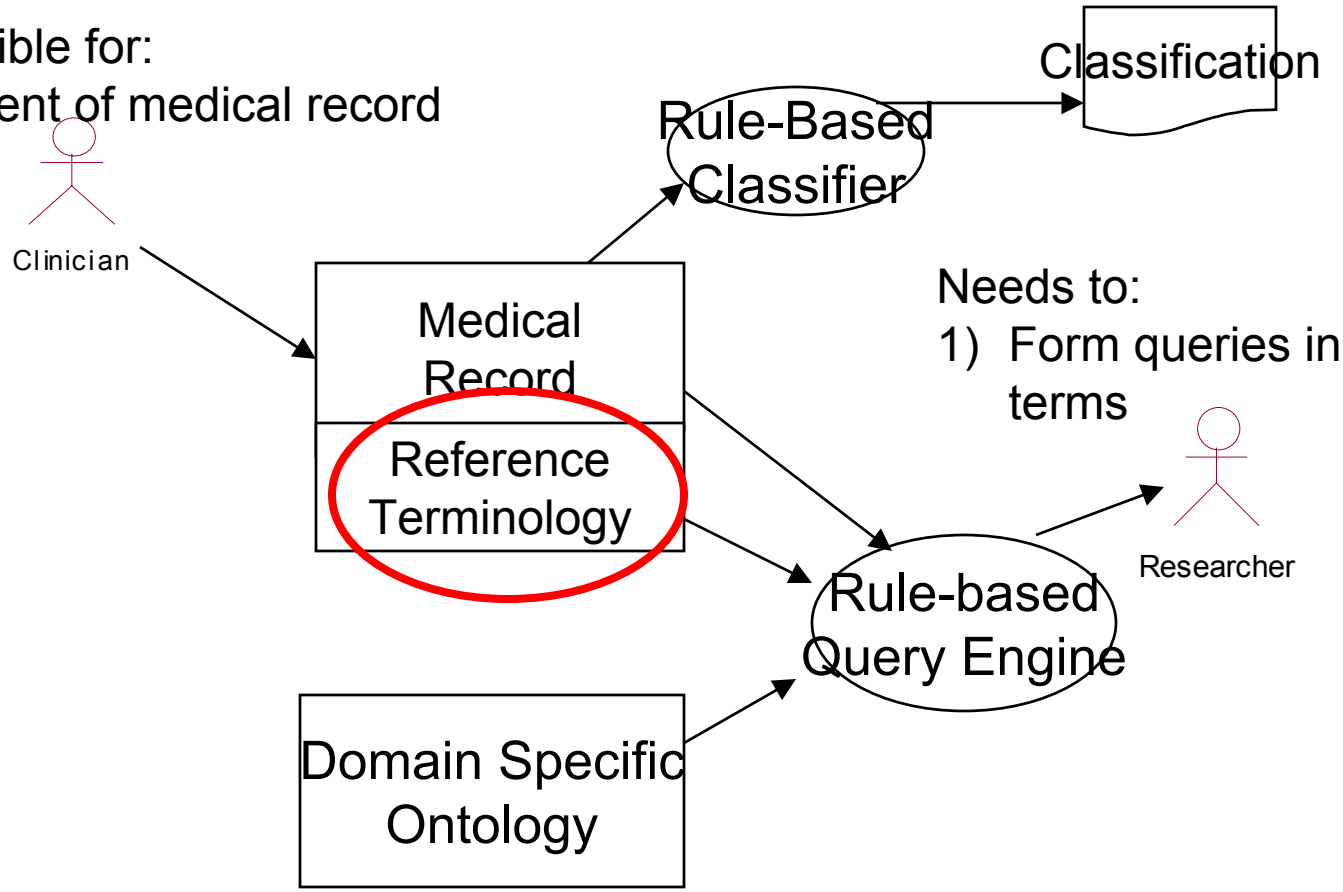
Some ways that the process can fail

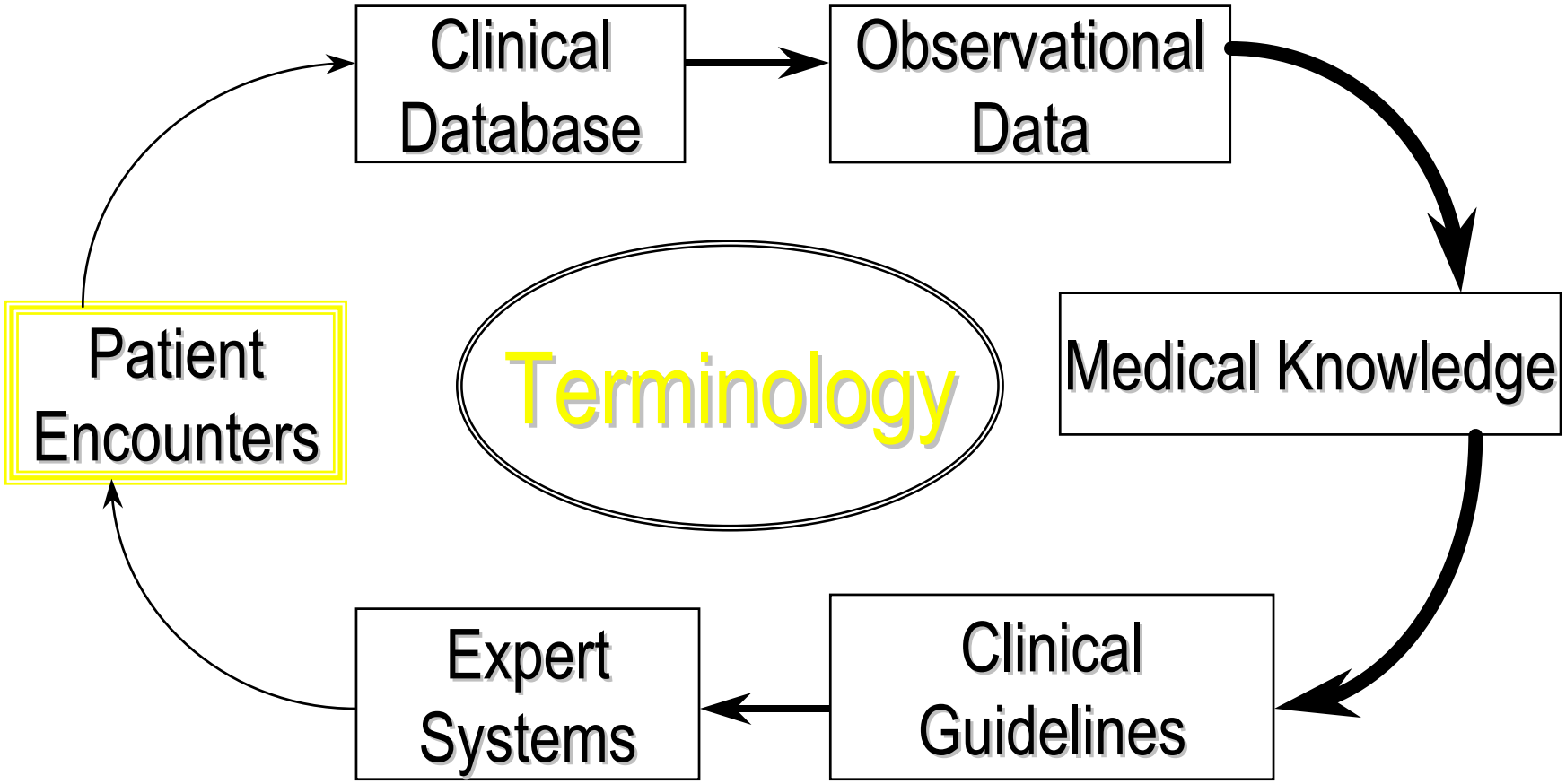
- Incomplete or inconsistent knowledge of classification rules
- Clinician resource time is scarce – billing record is often perceived as a part of the clinical record
- Indexing is resource intensive
- Indexing process depends on what is known at the time
- Researcher has to have intimate understanding of all parts of the process

Reference Terminology

Responsible for:
1) Content of medical record



Heritage of Continuous Improvement



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Reference Terminology

- Must represent fine level of clinical detail
- Coverage must be broad enough to span an entire discipline
- Must be well defined
- Must be compositional in nature
  - Post-coordination rules
  - Rules for determine compositional equivalence

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Characteristics of a Reference Terminology

- Requires computers and software to be effectively managed (3rd generation system)
- Terminology = content + software

Requirements for Specifying Software Behavior

1. **Information model –** What are the entities that are manipulated and how are they related?
2. **Requirements model –** What questions will the software need answer?
3. **Behavioral model –** How do request various behaviors, what do they do and how do they respond?

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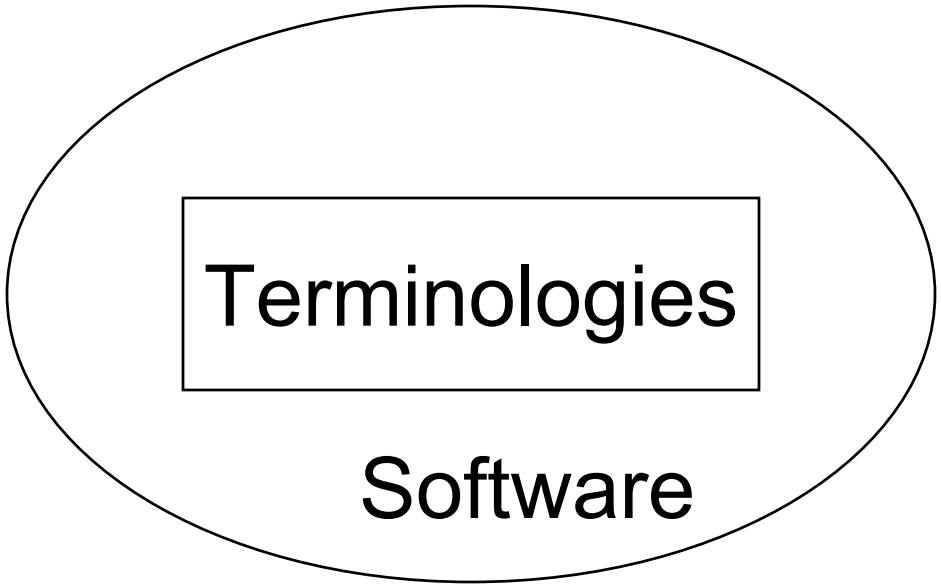
Reference Terminology



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Where we've been

Healthcare Data Dictionary
(Stan Huff / 3M)

- Evolved from the HELP PTXT system
- Software included:
  - Oracle DB running on Unix
  - Tuxedo transaction management system
  - OLE / C++ based client object system
- Reasonably successful
- Proprietary – content and algorithms didn't port

Lexicon Query Services (LQS)

- Developed under auspices of the Object Management Group (OMG)
- Read-only – no authoring
- Included:
  - Information Model of Terminology
  - Behavioral Model
  - Implementation Specification targeted for the Common Object Request Broker Architecture (CORBA)
    - Syntax specification in IDL
    - Architecture required significant changes in object/attribute layout

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LQS Specification

- Schema for globally unique identifiers
- Validate concept code
- Lookup Concept codes by word(s) / string / pattern
- Lookup concept text for a given context / language / lexical type
- Lookup definitions / comments / instructions
- List concepts that have a specified relationship with a supplied concept
- Determine whether two concepts are related
- Reduce a composite expression to a canonical form
- Compare two composite expressions
- ...

LQS

- Published in 1998
- Not widely used or adopted (outside of 3M)
  - Perceived (and actual) complexity of the specification
  - Not easy to implement
    - Services were not trivial to implement
    - No reference implementation
    - CORBA was difficult and expensive to work with
- Model and functional requirements are still reasonably definitive

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Mayo Terminology Services (MTS)
(Chris Chute / Mayo)

- Extension of Lexicon Query Services
- Purpose was to provide a complete “breadboard” of terminology components
- Added lexical/linguistic capabilities
  - Spell correction (word locator)
  - Word stemming (using LVG)
  - Word and Phrase completion
  - Plesionymy (words and phrases that could have a very similar meaning in a given context)
  - Candidate term matching

MTS 2000 Implementation

- Java based
- Used JDBC back end (Oracle / Sybase)
- Used SNOMED-RT Database model
- Multiple Implementation Architectures
  - CORBA
    - COM/DCOM bridge
    - Perl Bridge
    - Python Bridge
  - RMI
  - Straight Java Objects

MTS - Lessons Learned

Usefulness within Clinic depended on adoption by internal and external software providers

- Y2K came first
- Waited for HIPAA regulations to solidify
- Needed today's external incentives
  - HIPAA
  - Terrorism Surveillance
  - Bioinformatics

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MTS Lessons Learned

Usefulness within Mayo Clinic depended on adoption by internal and external software providers

- Specification needs to be
  - Standards based
  - (Relatively) easy to implement

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Where we are today

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Where we are today

- Open Terminology Services
- HL7 CTS Specification
- HL7 Terminology Tools
- LDAP Back End
- OTS Using LDAP and Lucene
- NLP processing of medical records and term source

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Open Terminology Services

- Refactoring of MTS
- Standards Based:
  - CTS through HL7
  - “Open Source” approach
    - Java Reference implementation
    - LDAP back end
    - ... serious clash w/ Mayo culture

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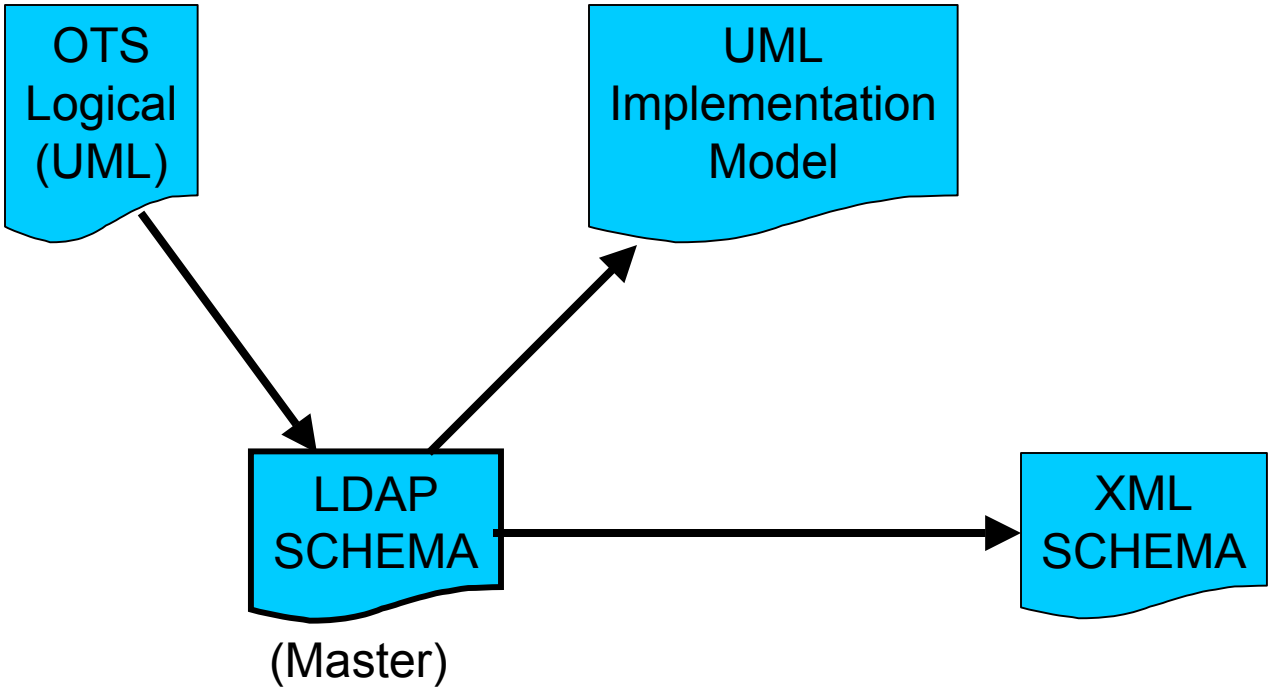
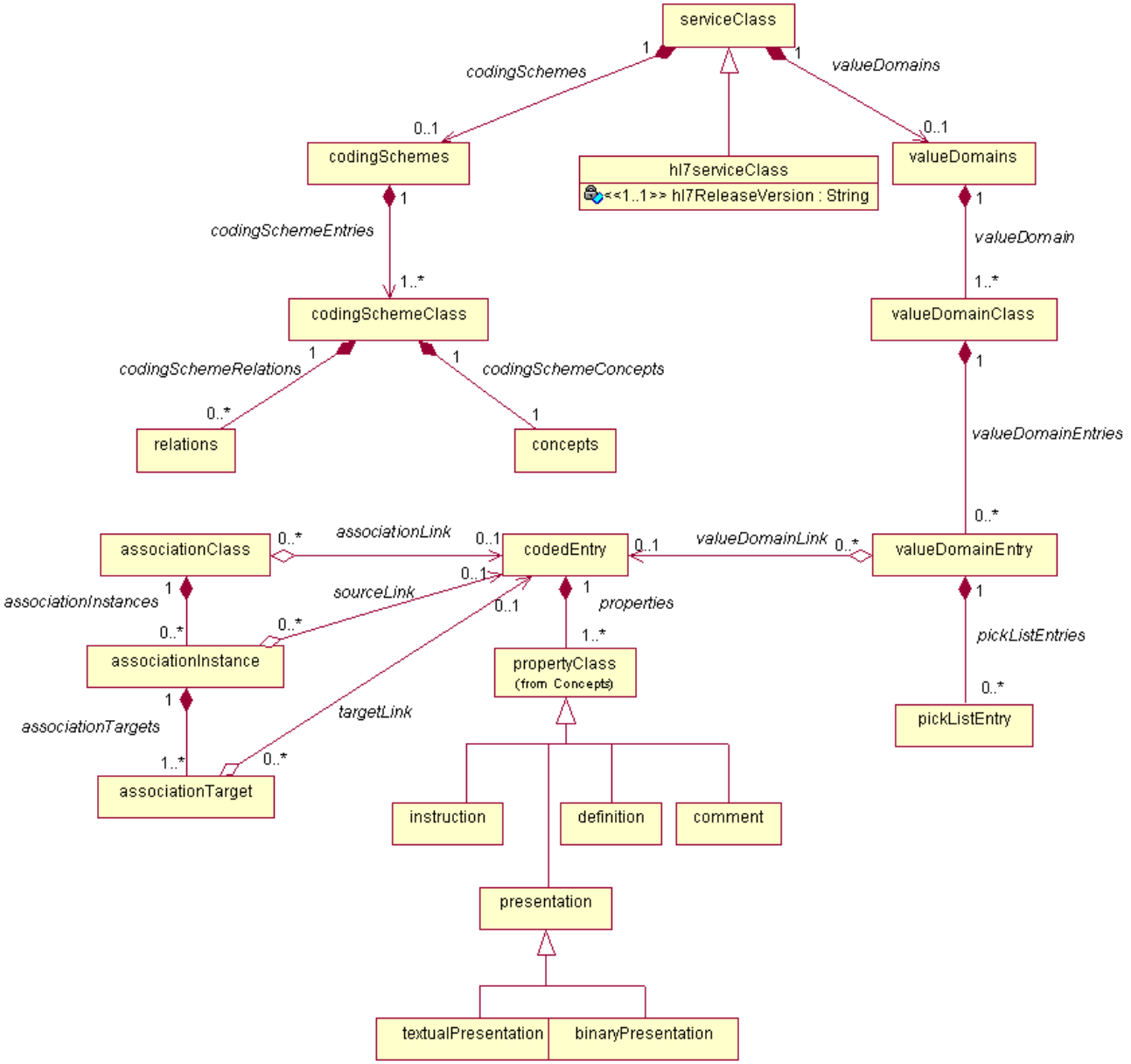
OTS Components

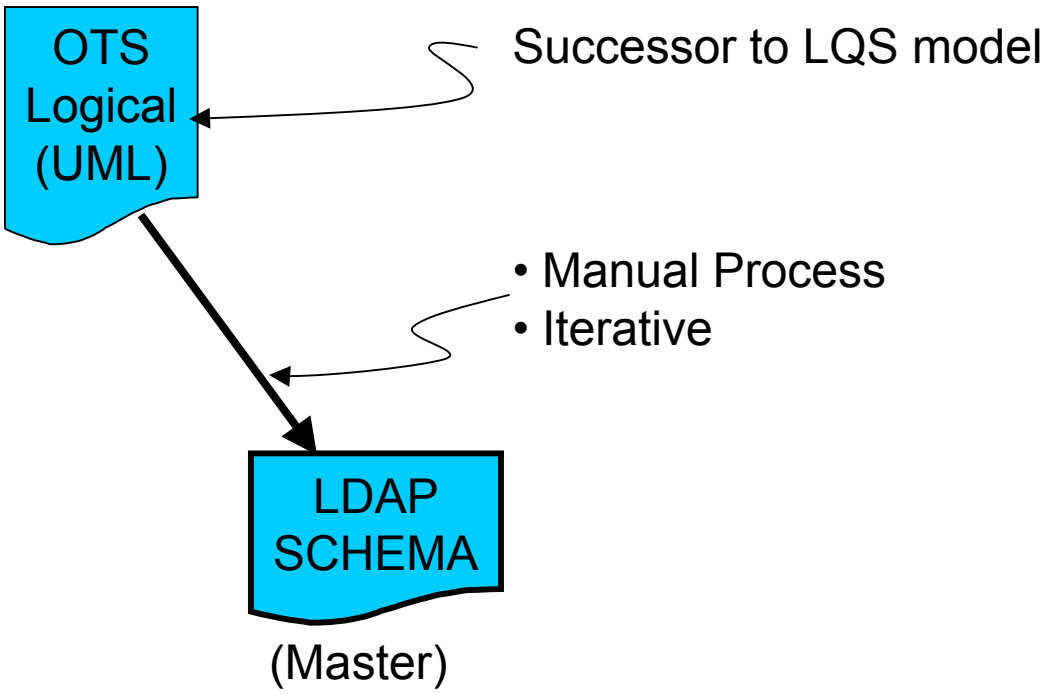
- Model
  - Abstract ('logical') model of information content
  - Implementation models – one per technology
- Content
  - Terminology content deployed in various technologies
- Software
  - Browsing and Implementation Tools
  - Distribution and deployment tools
  - Editing and revision tools

OTS Model

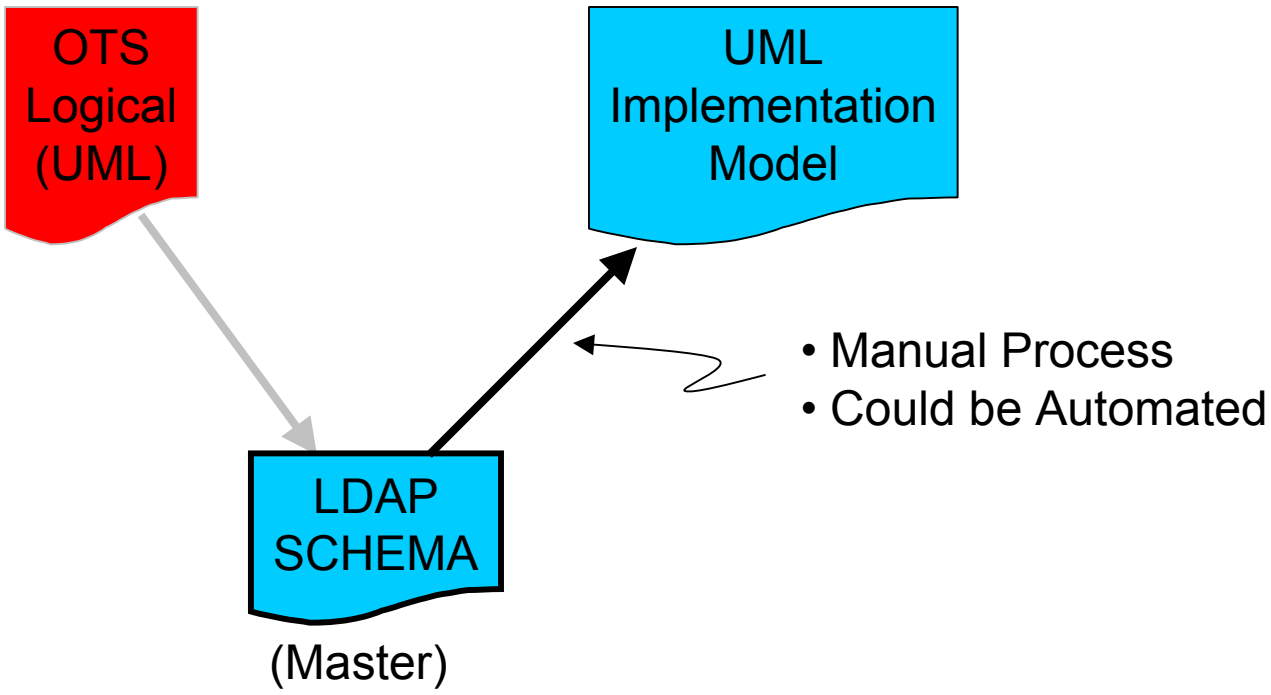




OTS Model
Logical Model & Schema

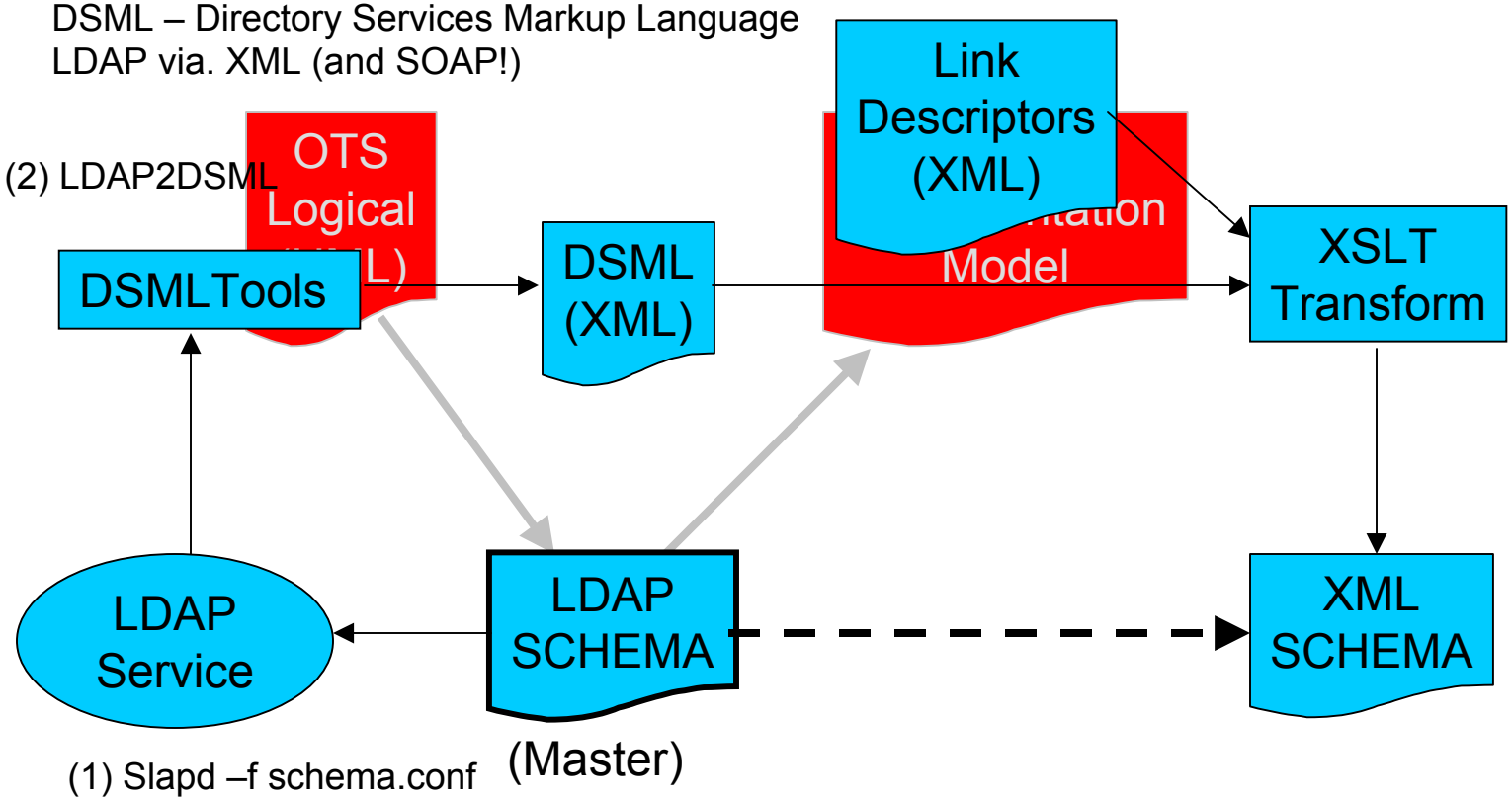


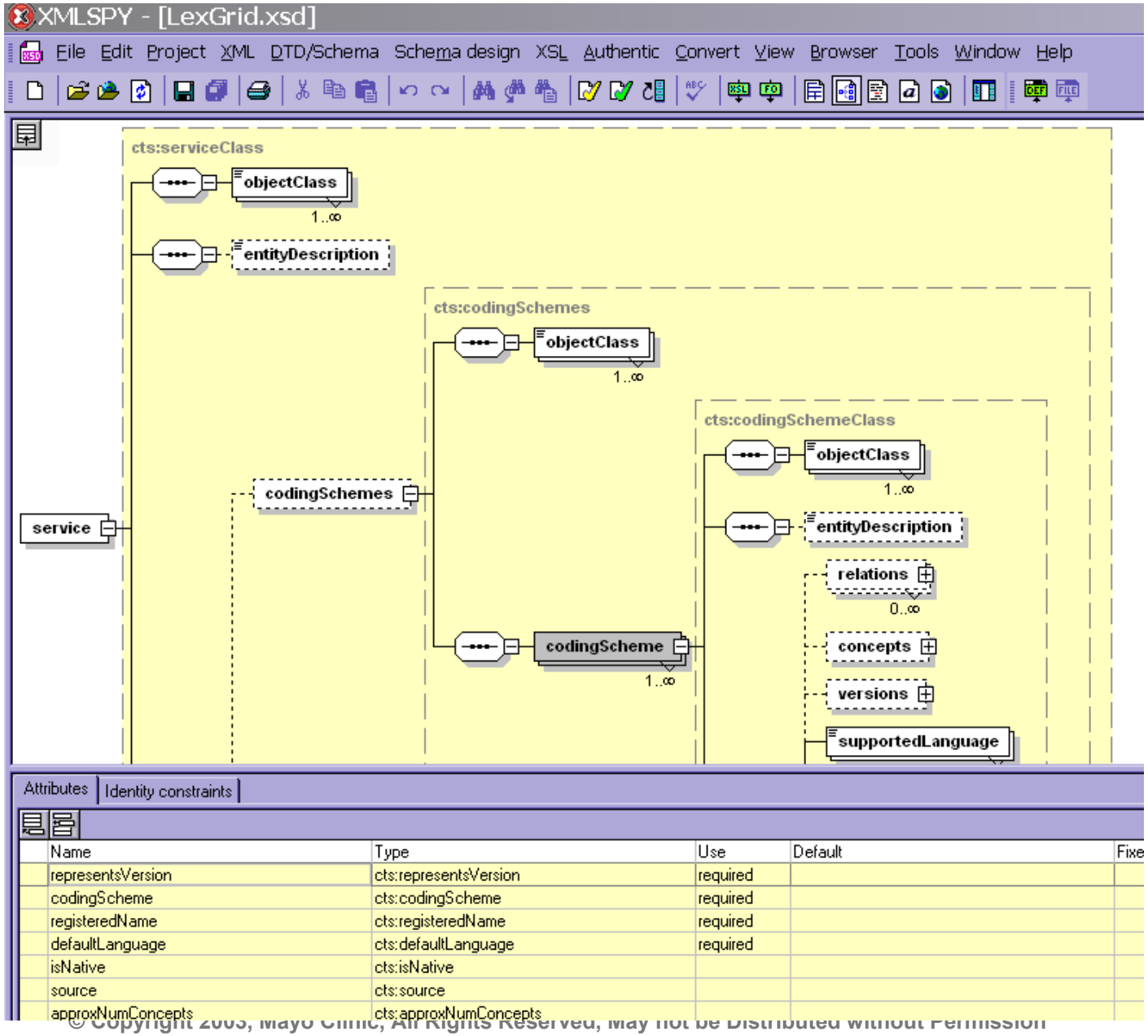
OTS Model
Implementation Model



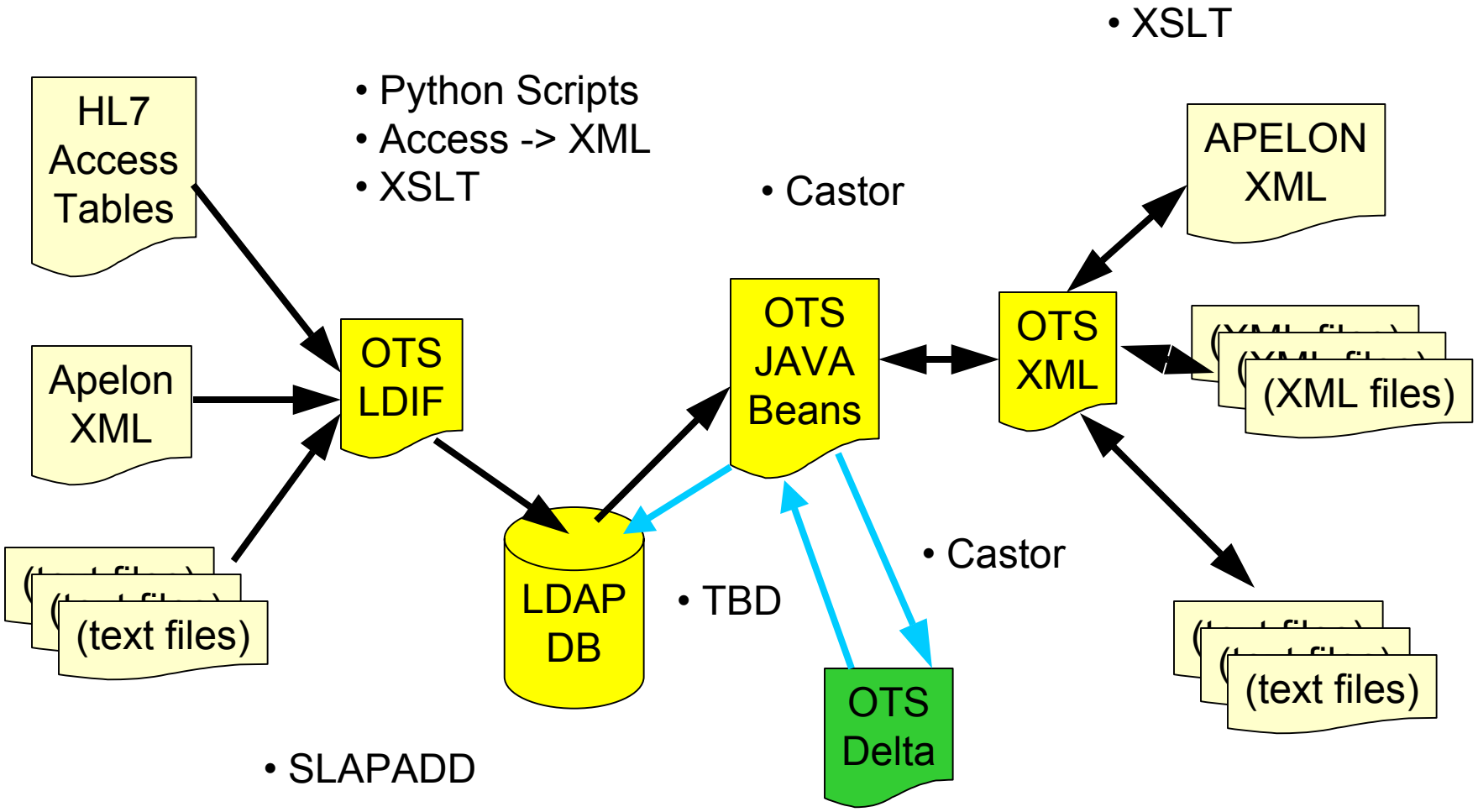
OTS Model XML Schema

DSML – Directory Services Markup Language
LDAP via. XML (and SOAP!)

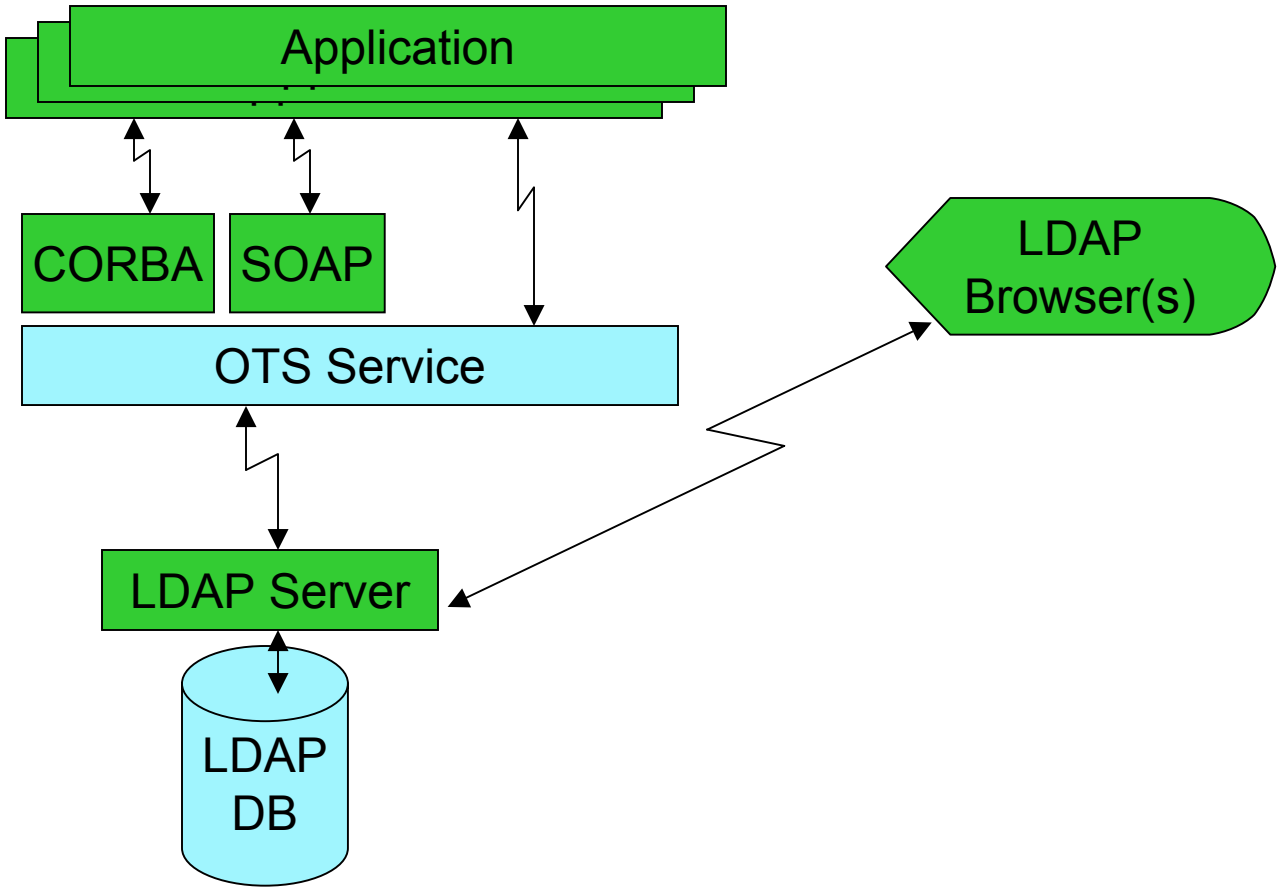




OTS Content



OTS Software
Browsing and Implementation Tools



LDAP Back end

- Lightweight Directory Access Protocol
- Used for publishing read-mostly, high-availability directories of “things”:
  - People
  - Resources
  - Organizations
  - Java Services
  - ...

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LDAP Characteristics

- Hierarchical directories of information
- Focus is read-mostly information
- High availability, high reliability
- Supports data replication
- Reasonable security model
- Supports distributed hierarchies (federation)
- Both open source and commercial tools are widely available

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Why LDAP?

- Widespread availability
- The hope is that vendors will find it easier to load their own content into a generic data model than it would be to write a service implementation themselves.

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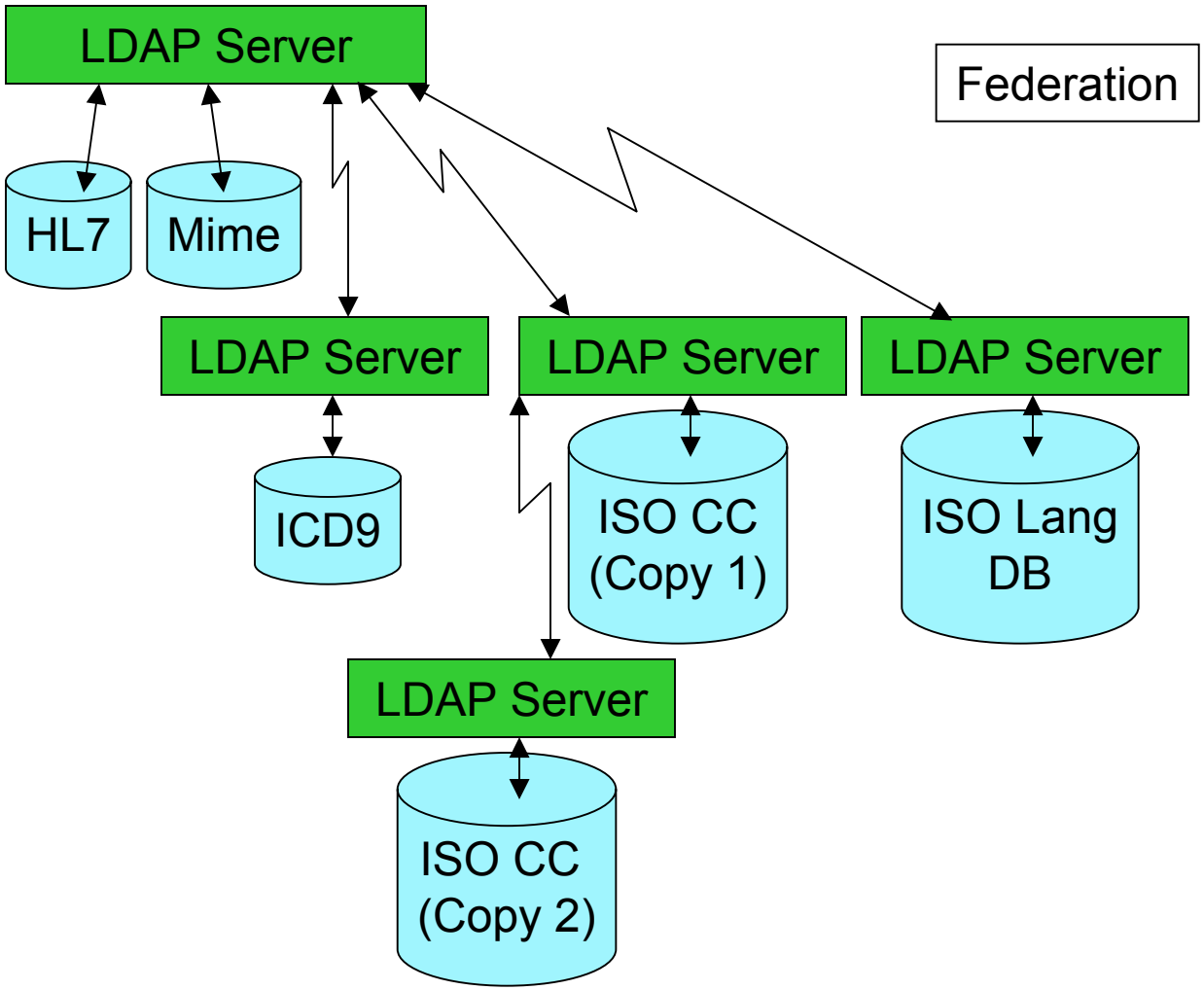
LDAP Back End

- Currently publishing HL7 & related terminologies
- Software & Demo can be found at

  http://www.terminologyservices.org

OTS Software Distribution and Deployment



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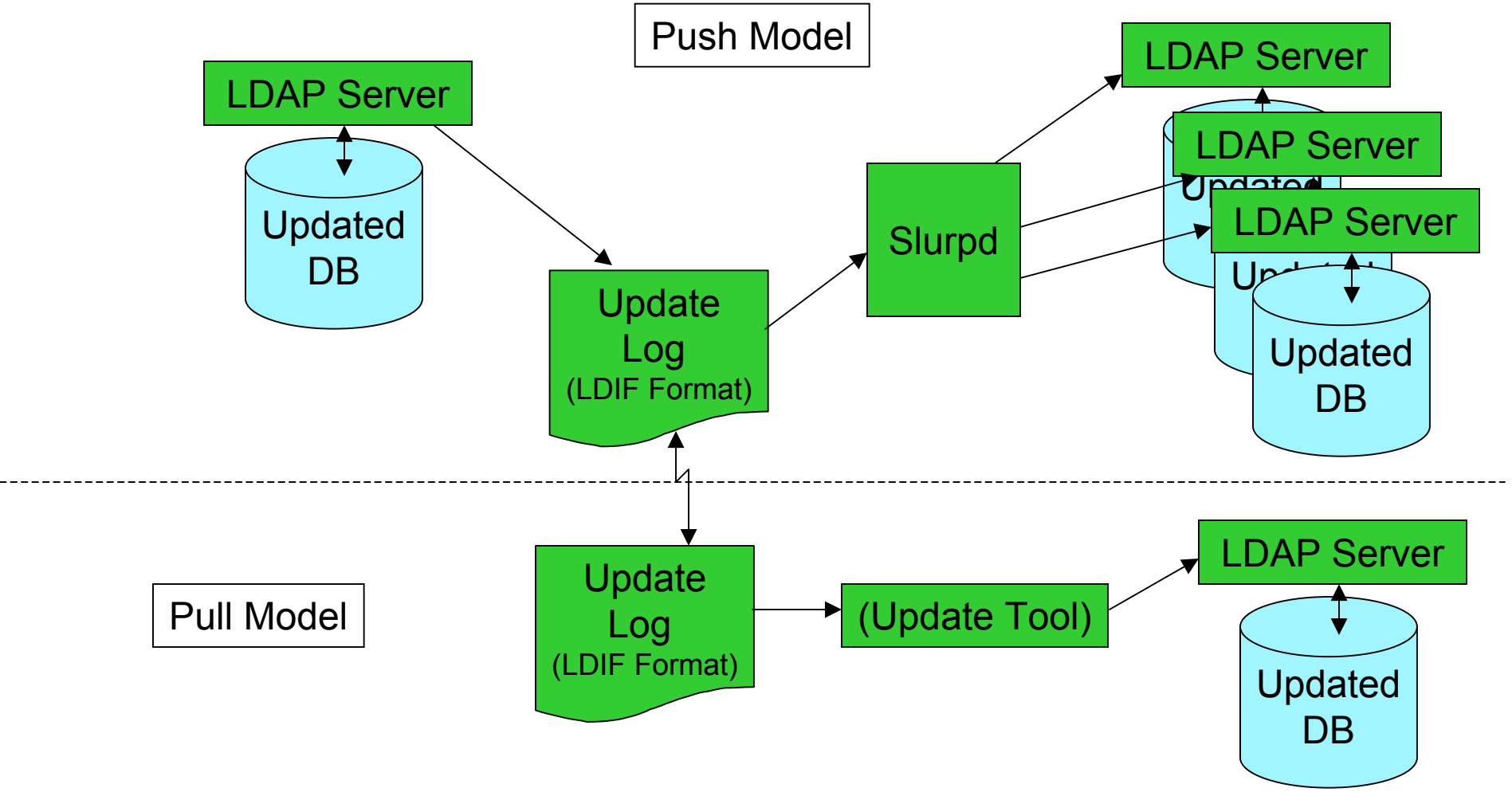
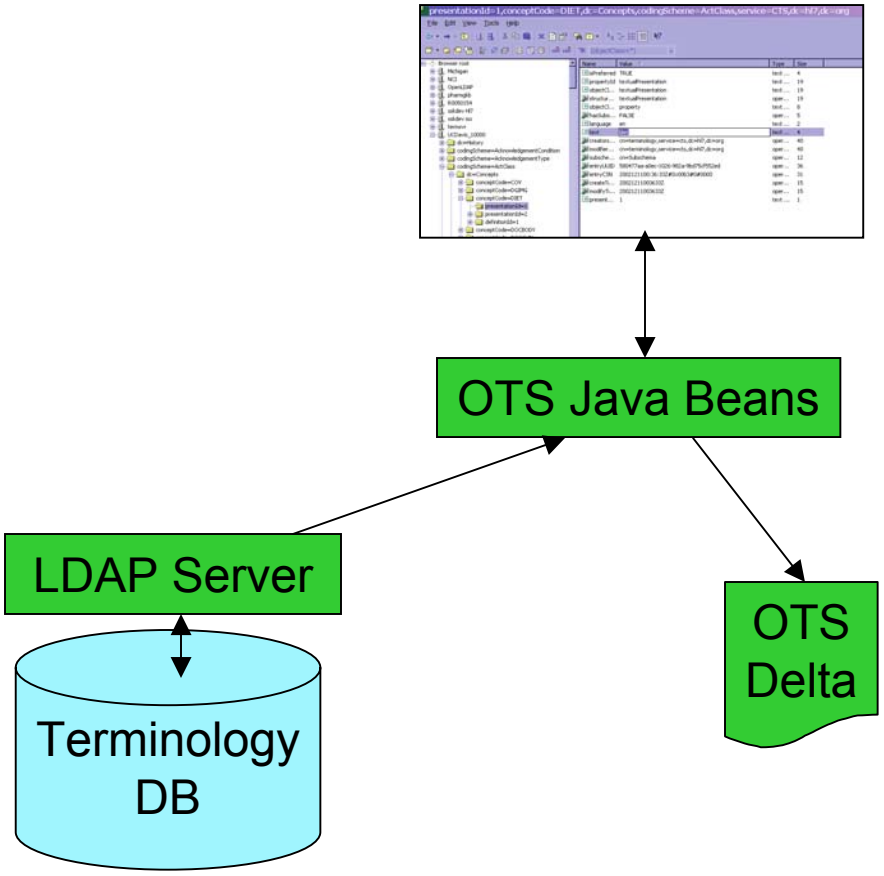
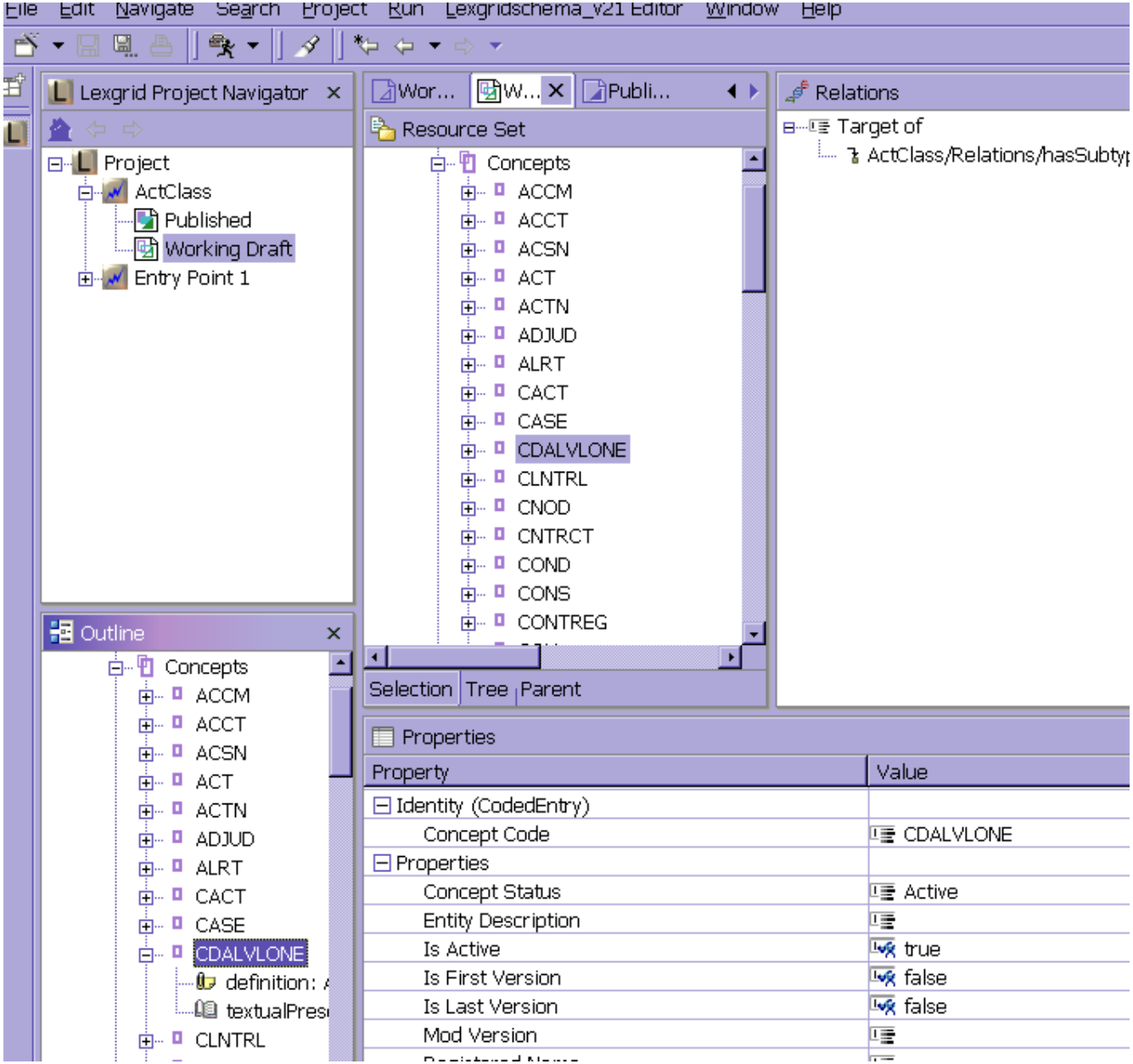
OTS Software Distribution and Deployment

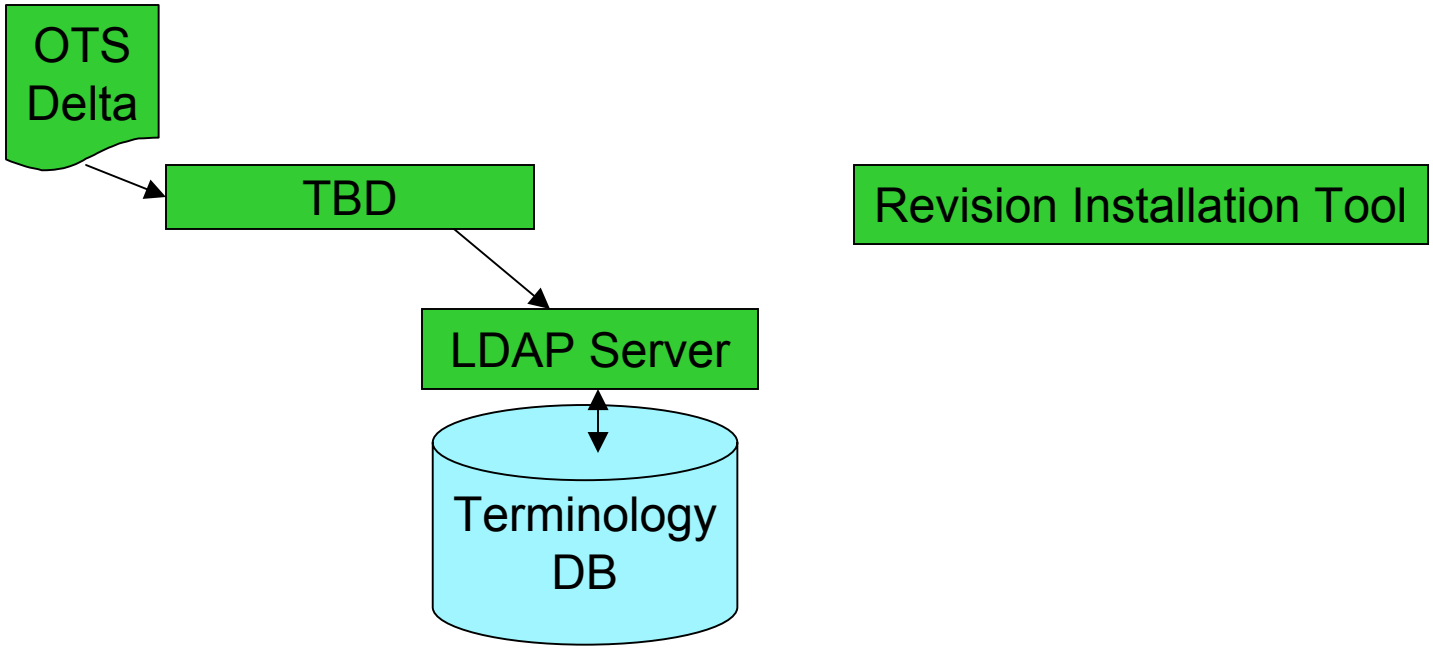


OTS Software Editing





OTS Software Revision



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Open Terminology Services MTS Extensions

- Creating new indexing strategy w/ distributed LDAP back end
- Lucene based
- Enhancing thesaurus with various semantic distance algorithms
- Alpha should be available shortly

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HL7 CTS Specification

- Specification divided into two parts:
  - Messaging layer – speaks HL7 messages, data types & process
  - Vocabulary layer – speaks code systems / terminology
- Still under revision
- OMG IDL being used for syntax portion
- Having to juggle needed functionality and perceived simplicity

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HL7 CTS Specification "Reference" Implementation

- Native Java or SOAP based
- Messaging API uses JDBC back end
- Vocabulary API uses LDAP back end
- Demonstration code (0.8) and source available on web

  http://www.terminologyservices.org

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HL7 Terminology Tools

- Supporting HL7 Vocabulary Maintenance
- XML-Based Submission Format
- Processor and update tool
- Still need to reintroduce historical part
- Editing tools pending:
  - Apelon
  - Health Language Inc?
  - Internal editor under development
  - Protégé?

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Open Terminology Services Content

- Once implemented how do we:
  - Import and export code systems from the service?
  - Cross-reference content?
  - Post and distribute updates?
  - Edit and revise content?

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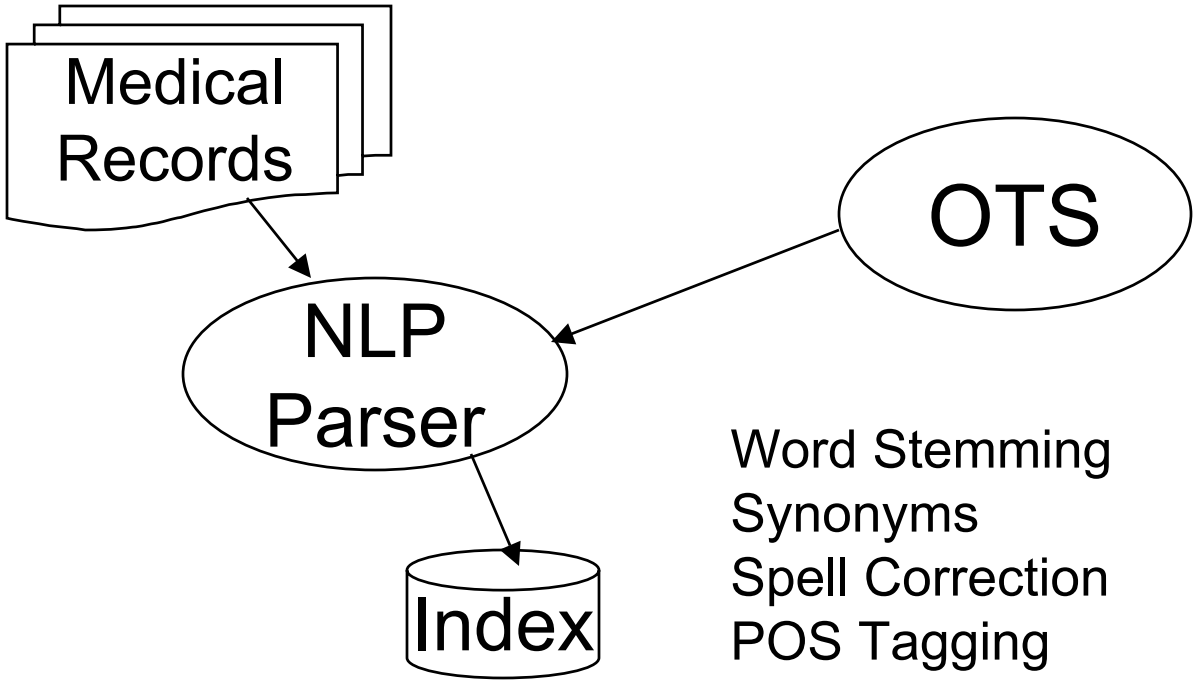
Indexing and Cross Referencing

- Graphic of OTS & Lucene index
  - Mention of thesaurus and semantic distance stuff
  - Mention of spelling issues

NLP Based Medical Record Indexing



Word Stemming
Synonyms
Spell Correction
POS Tagging
Semantic Distance Metrics

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Where we are going

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Vision

- The Lexical Grid
- Blurring the Terminology / Information Model Boundary
- Terminology on the front end

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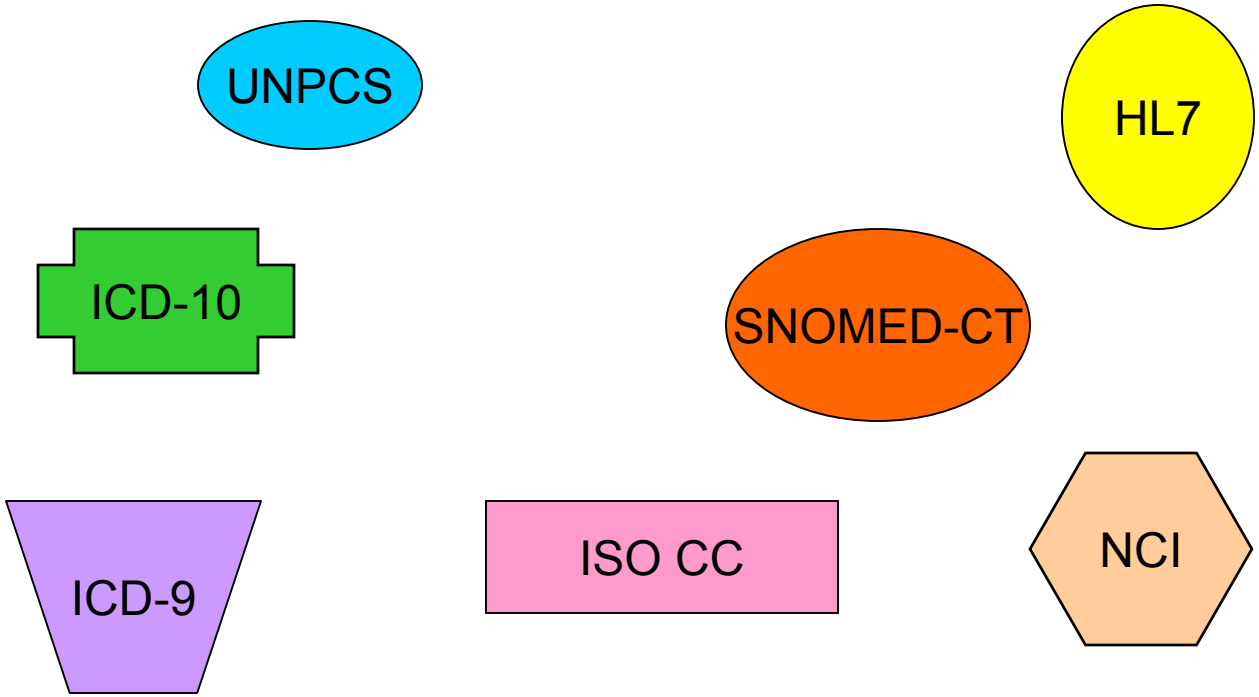
The Lexical Grid

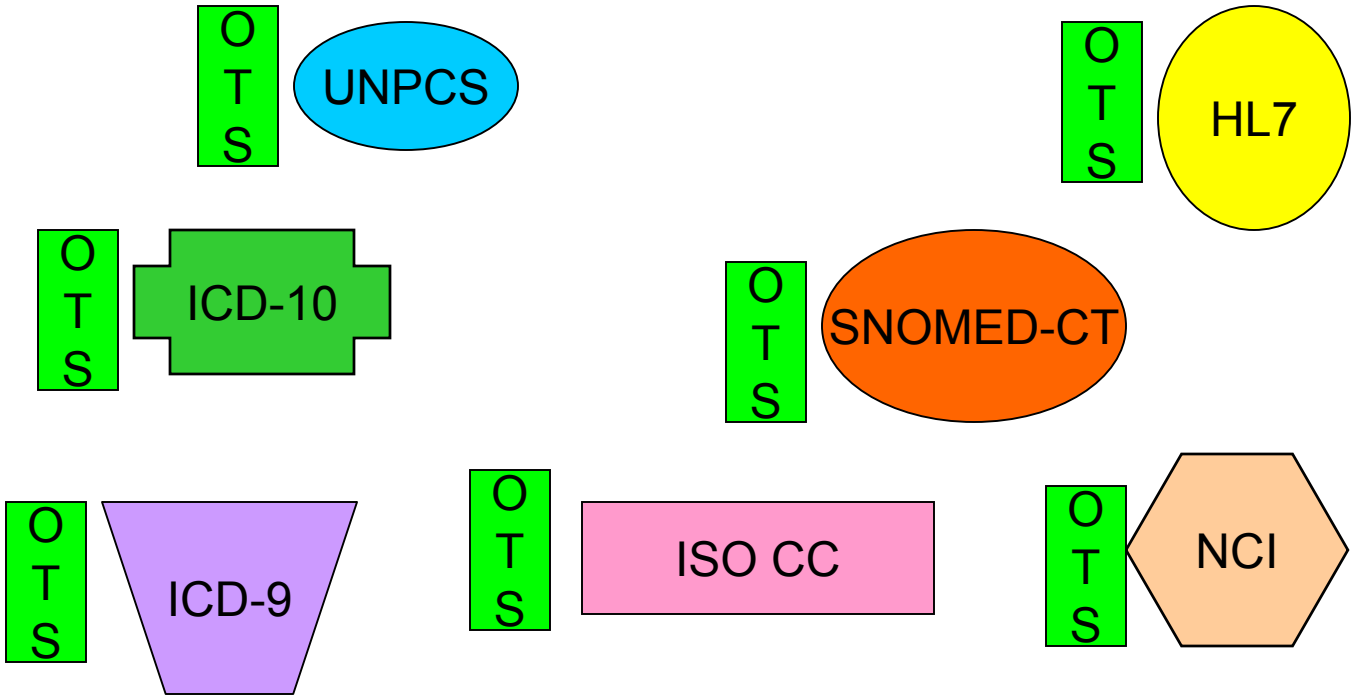
A heterogeneous, distributed collection of terminologies...

- ...linked by a common API
- ...coupled to shared indices
- ...capable of being extended, enhanced an annotated in a loosely-coupled, distributed fashion

A Heterogeneous, Distributed Collection of Terminologies



Linked with a Common API



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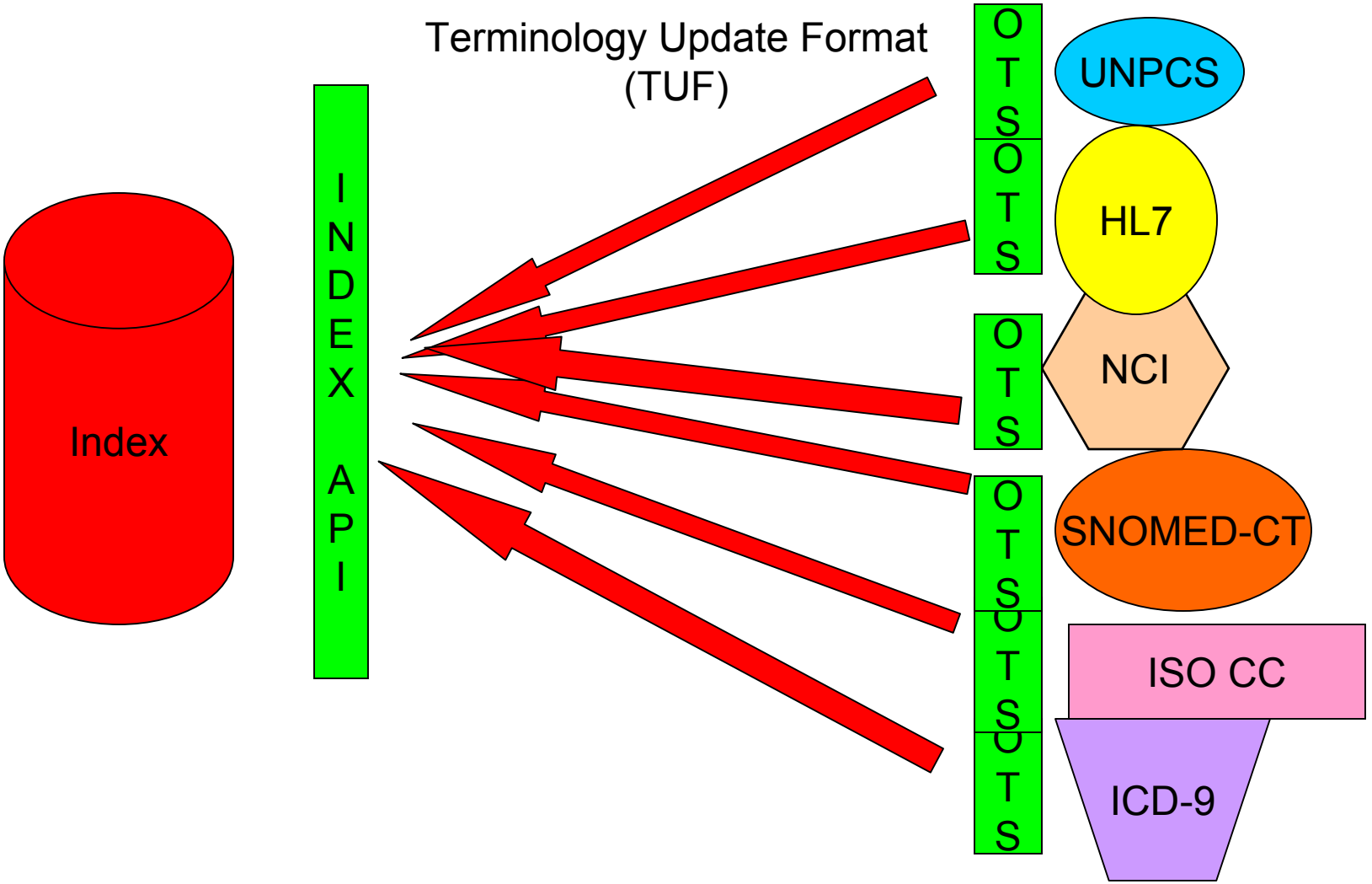
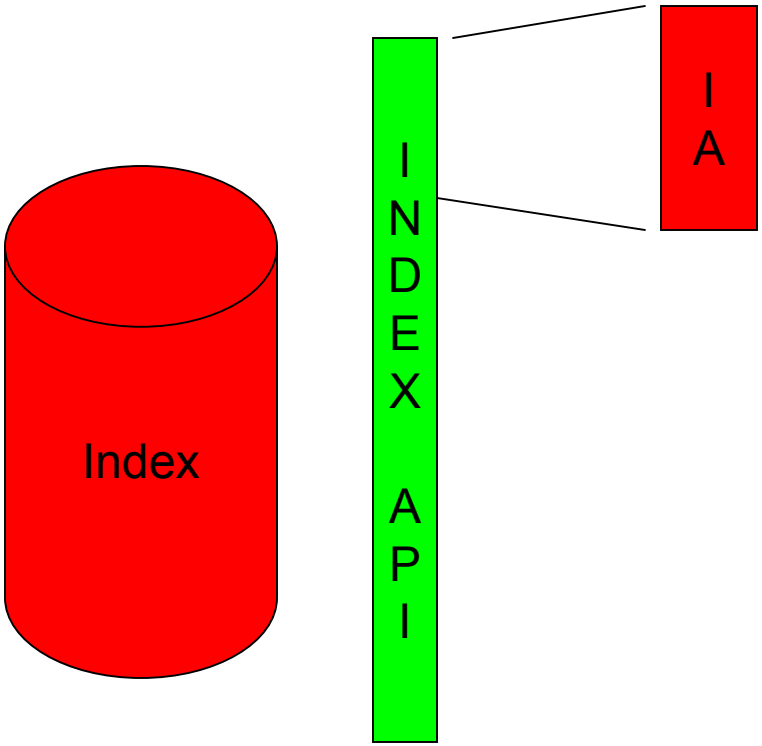
Coupled to Shared Indices



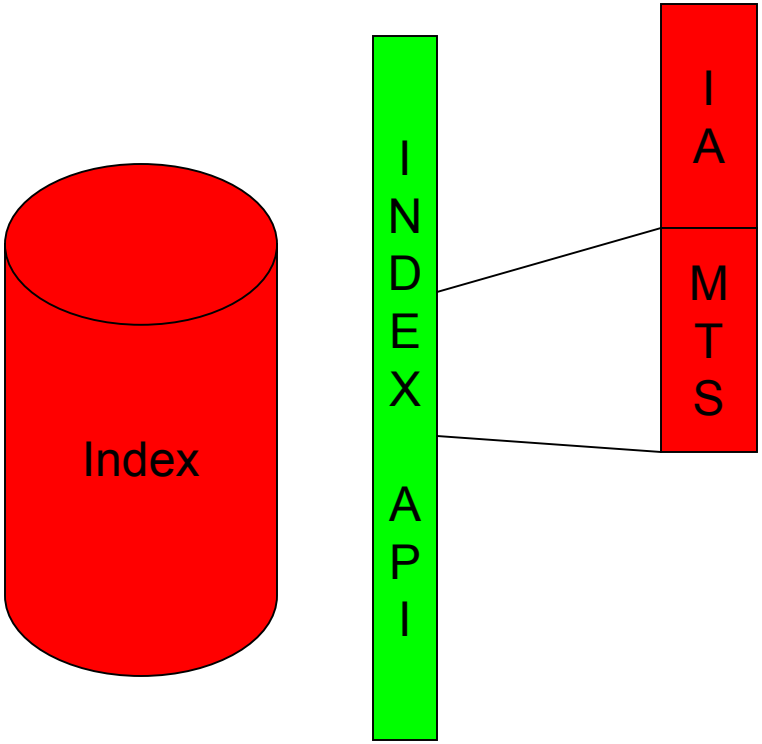
Index API
Generating an Index



Index This (Id, {(type, text)}
Update Index(Id, {type,t ext)}
Unindex (Id)
Unindex(part ID)

ID – URN
part ID - entire terminology
Need URN -> Service Map

Index API
Query Interface



MTS ++
List ID's (code system/concept)
Matching(phrase, semantic type, etc)

Query -> Id list (csid + code)

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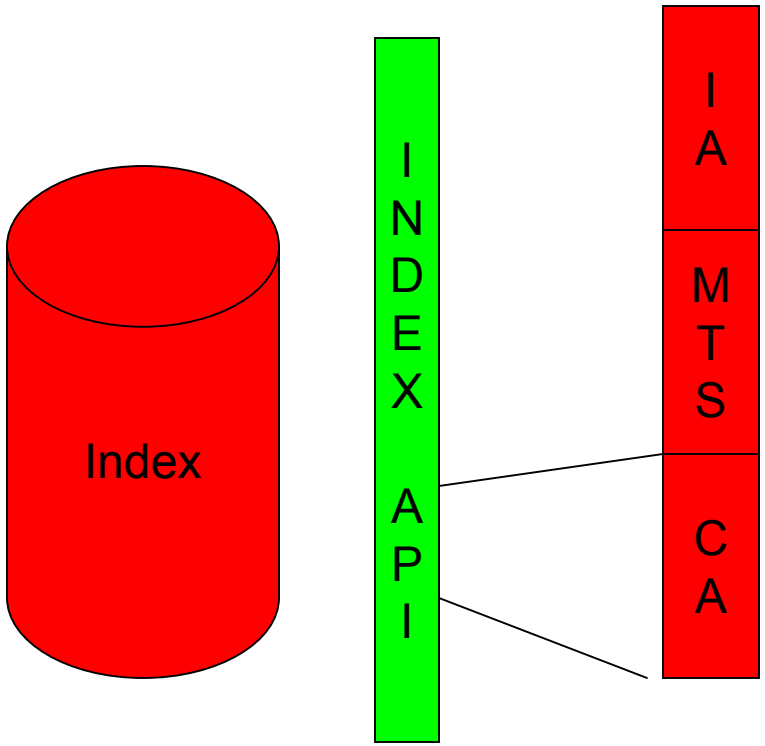
Index API
Consolidated API



Presents Terminological Space as a Single entity

Consolidated OTS Query – user has no need to query individual vocabularies

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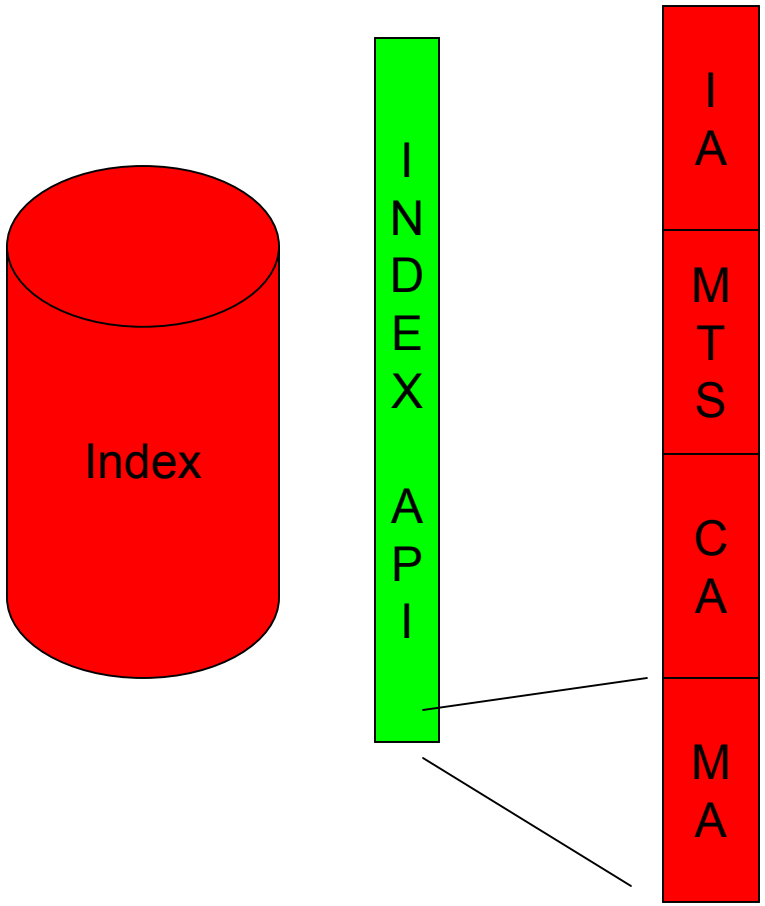
Index API
Maintenance API



ManageThesaurus
Spelling Dictionaries
Other indexing packages

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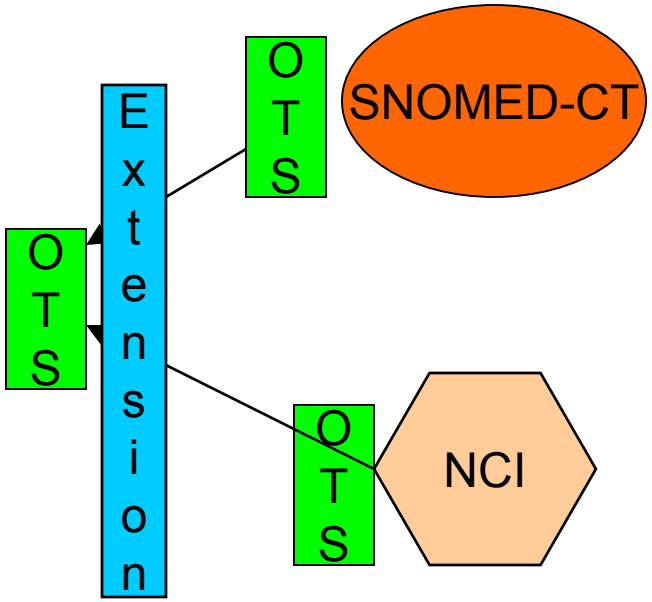
Extended, enhanced an annotated in a loosely-coupled, distributed fashion



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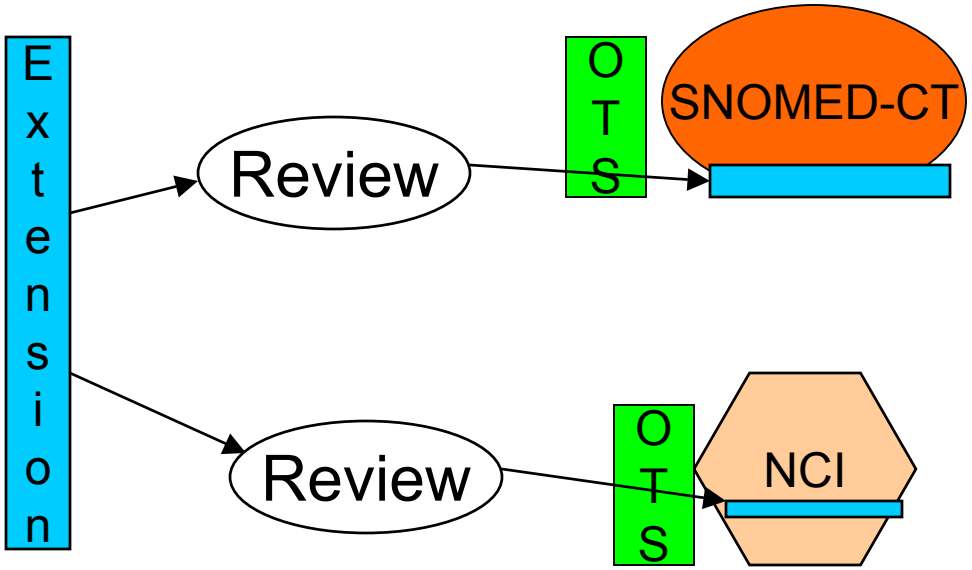
Extended, enhanced an annotated in a loosely-coupled, distributed fashion



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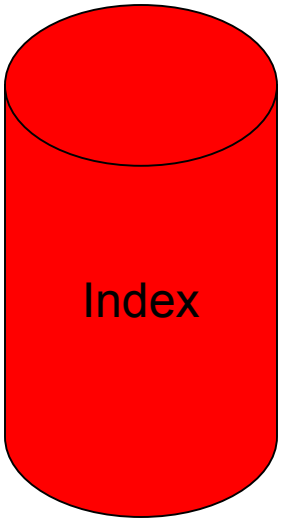
Index



- Misspelling tolerant
- Plesionyms
- Morphological Roots
- Phrase Library
- POS Aware
- Co-occurence info
- N-grams
- Etc...

Blurring the Terminology / Information Model

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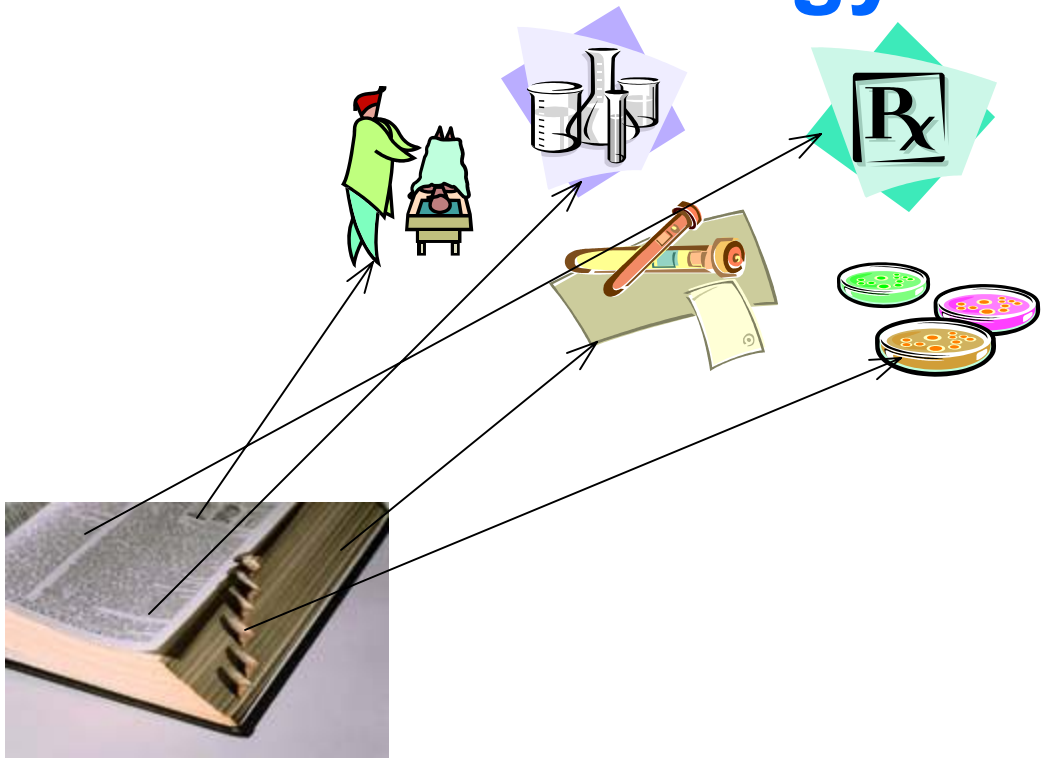
Terminology



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Information Model

- Selects the subset of the 'real world' to be discussed in a given context
- Utilizes elements in the terminology
- Tacit or explicit agreements on what is to be:
  - Ignored
  - Refined
  - Expanded and augmented
- Extends the terminology model with non-definitional characteristics

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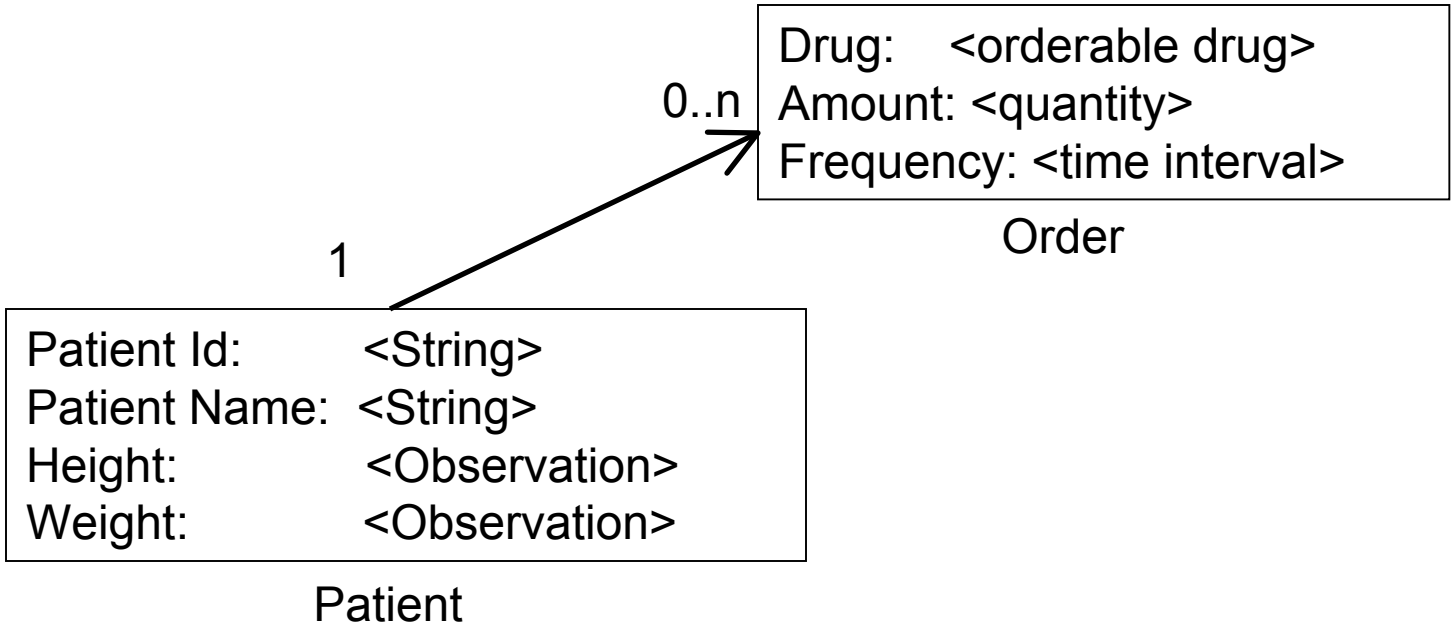
Information Model



Pharmacy Orders

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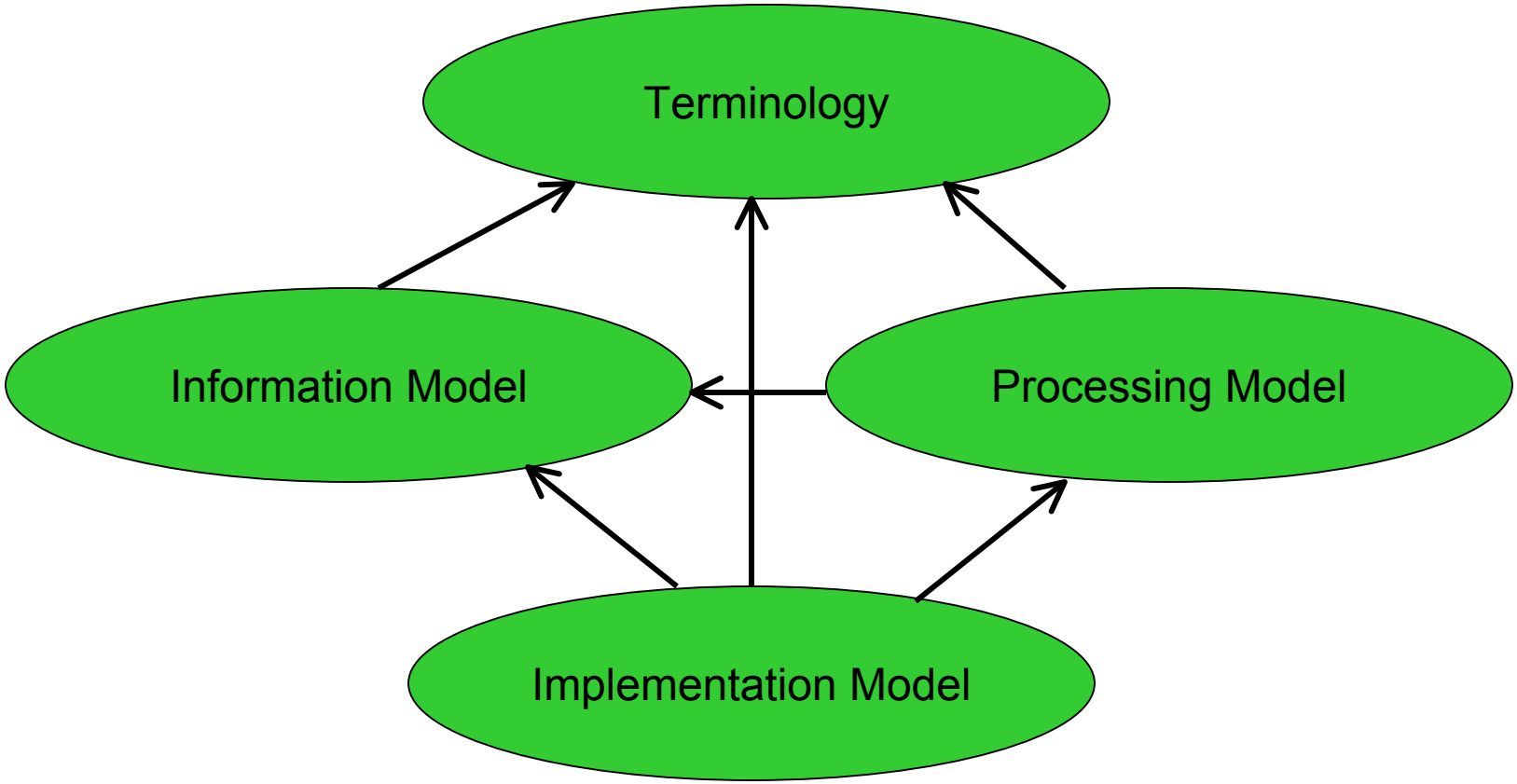
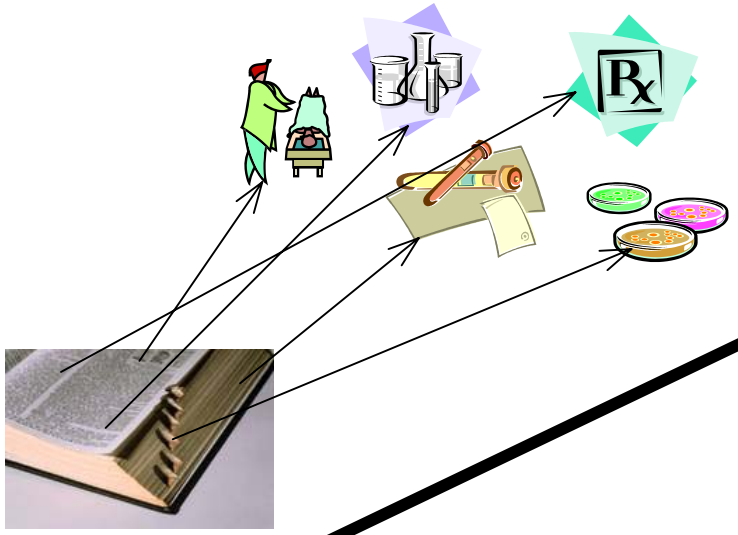
Dependencies
(Borrowing heavily from RM-ODP)



How Do We Link...



Drug: <orderable drug>
Amount: <quantity>
Frequency: <time interval>

Order

Patient Id: <String>
Patient Name: <String>
Height: <Observation>
Weight: <Observation>

Patient

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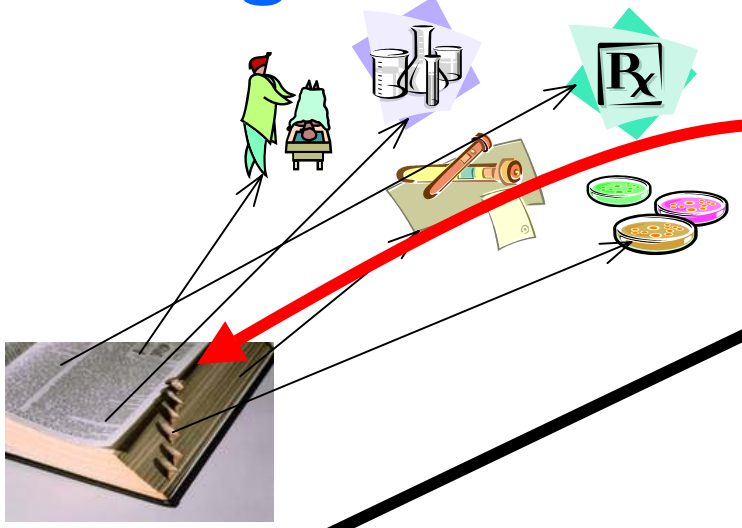
Linking at the Attribute Level



Drug: <orderable drug>
Amount: <quantity>
Frequency: <time interval>

Order

Patient Id: <String>
Patient Name: <String>
Height: <Observation>
Weight: <Observation>

Patient

Pharmacy Orders

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Database Granularity

The same information can be carried in widely varying structures:

A code in a table

PT#	observation
1110112	**Heart murmur**

Tag/Value Pairs

PT#	Tag	Value
1110112	**Observation**	**Murmur**
1110112	**Location**	**Heart**

Free text

PT#	observation
1110112	**"Findings indicate a pronounced apical murmur throughout the entire systolic phase…"**

Column Headings

PT#	Heart Murmur
1110112	**TRUE**

Table Names

PT#
1110112

Table 17: Patients with Heart Murmur

Database Names

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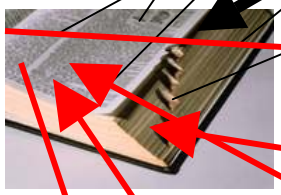
Linking at All Levels



Drug: <orderable drug>
Amount: <quantity>
Frequency: <time interval>

Order

Patient Id: <String>
Patient Name: <String>
Height: <Observation>
Weight: <Observation>

Patient

Pharmacy Orders

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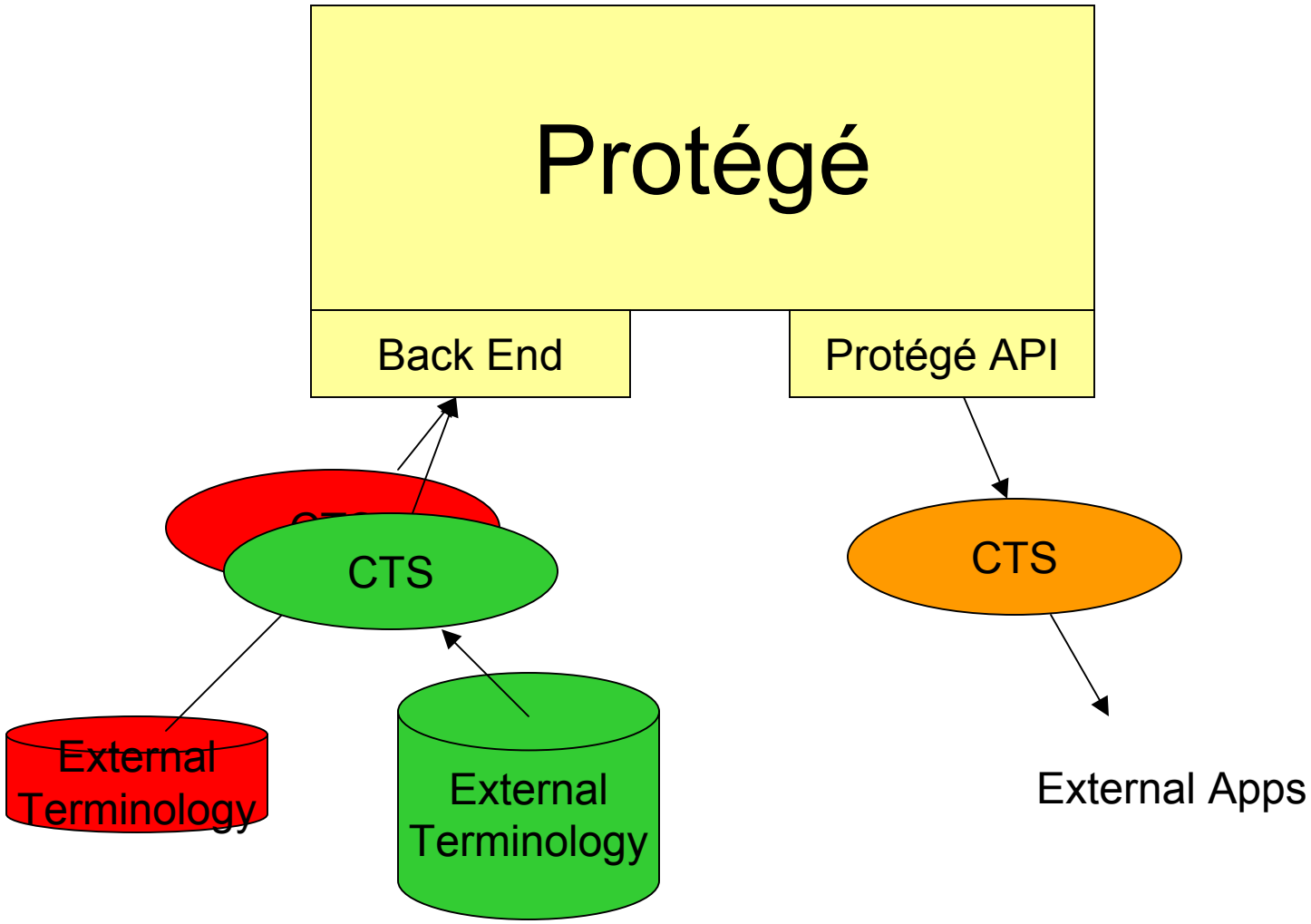
Proposed Approach



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Protégé

- Promoted as an ‘ontology’ editor
- Frame based – no integrated classifiers
- Open source / open architecture
  - > 50 User written add ons
    - Graphical Browsers
    - Reasoning Engines
    - Back Ends
    - Different Input and Browsing forms
  - Currently being integrated w/ OWL

Protégé and CTS/OTS

1. **Protégé needs a strong terminological link**
   - **Words or sets_of_words within an ontology are not sufficient**
   - **Need to be able to reference and reuse wherever possible**
   - **External terminologies should be available in the Protégé metaphor**

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Protégé and CTS/OTS

2. **Protégé authored ontologies need to be accessible to a wide variety of applications**
   - **Protégé API is one option**
   - **Exposing Protégé authored material via. terminology services is a second**

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Terminology on the Front End

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Terminology on the Front End

Tools, standards, and API's that allow the clinician to quickly, accurately enter information in an clear, unambiguous fashion

- **Spelling**
- **Phrase library**
- **Dictionaries**
- **Compositional tools**
- **Data driven forms**

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Terminology on the Front End

Step 1: Standards

- Standard message formats
  - HL7 and derivatives
- Standard terminologies
  - OHT, UMLS++, Lexical Grid
  - SNOMED-CT (???)
- Standard plug-n-play tools
  - CTS, OTS, CCOW, ???

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CTS / OTS Merger

- CTS – Common Terminology Services
  - HL7 specification under development
  - Attempt to balance simplicity and capability
  - Subset of OTS
- (Hopefully) Version 2.0 & OTS will be one in the same.

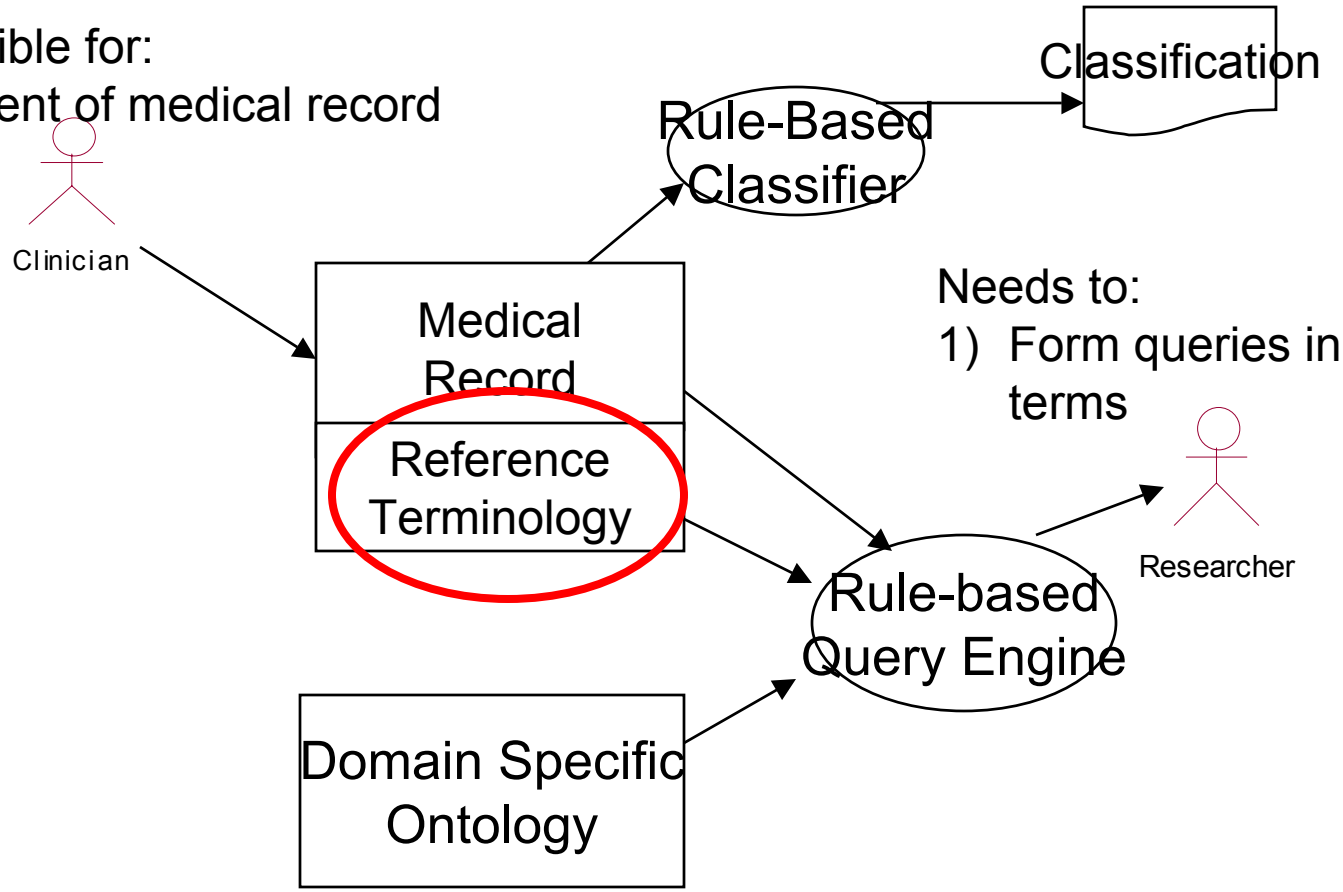
Composition and Federation

OWL and Terminology

- OWL – Web Ontology Language
  - Focus is on formal “definitions” – an entity is defined by its position in a lattice
  - Lexical aspects underspecified
    - Textual definitions and references
    - Representations / languages / contexts / linguistic forms
- Merger point may be in Protégé
- Alternative may be a transform between LexGrid model and OWL

Reference Terminology

Responsible for:
1) Content of medical record



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Composition and Federation

- A single integrated code system is still a long way off
  - Some would argue that it will never occur
- Clinical statements will need to be made using multiple terminologies:
  - ICD-9 - ISO 639
  - LOINC - RxNorm
  - HL7 - ...
  - SNOMED-CT
  - ISO 3166

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Composition and Federation

- The boundary between ‘information mode’ and terminological model will continue to be fluid
- How do we achieve consistent, comparable results across
  - Pre-Coordinated terms
  - Information Model
  - Terminological constructs

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Composition and Federation

- **Part of:**

  NLM Grant 1R01LM007319-01A1

  "Development and Evaluation of Terminology Services"

Summary

- Terminology is both content and software
- Both content and software need to become widely available
  - In a variety of formats
  - For a variety of platforms
- Mayo continues to research and develop:
  - Standardized terminology service software
  - Tools for editing and distribution
  - Mechanisms for combining terminology, information models and implementation

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Acknowledgements

NLM 1R01LM007319-01A1

"Development and Evaluation of Terminology Services"

NIST FAA 70NANB1H3049

"Standards-Based Sharable Active Guideline Environment"